AUGUST 1957

Journal

VOL. 49 • NO. 8

AMERICAN WATER WORKS ASSOCIATION

The Raritan River —Dam it all and solve New Jersey's water supply problem?

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NEW JERSEY WATER SUPPLY
Meyner, Baumer, Capen

UTILIZING WATER RESOURCES
Merryfield, Shelton

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METHODS FOR METHANE DETERMINATION
Committee Report

REMOVAL OF RADIOACTIVITY
Swope

ADVANTAGES OF MONTHLY BILLING
Agnew, Jordan

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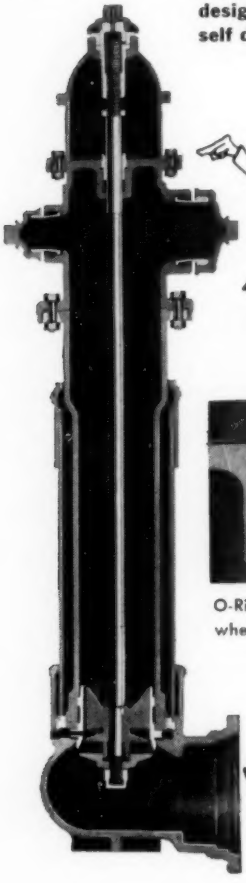

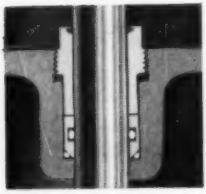

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Journal

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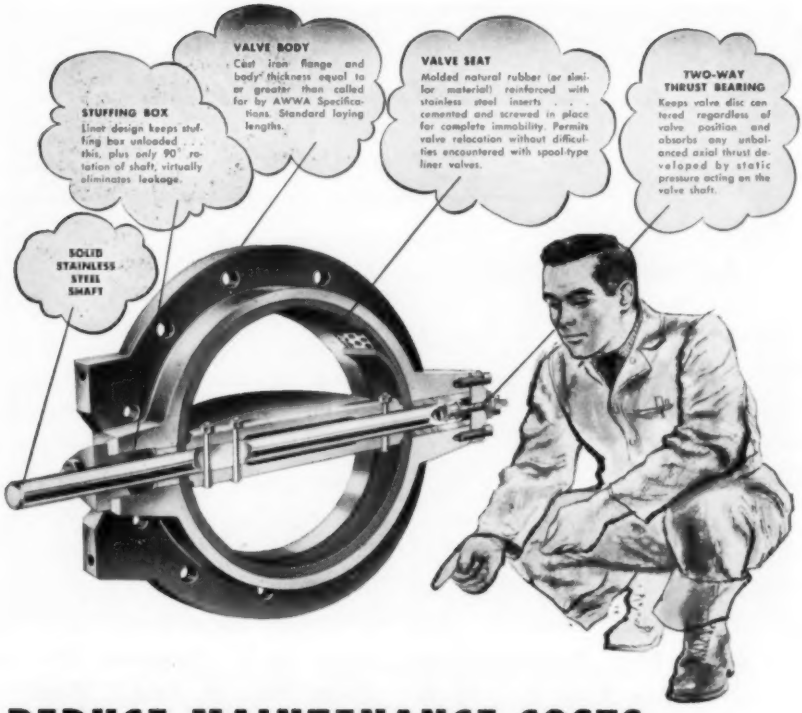
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Coming Meetings

AWWA SECTIONS

Sep. 4–6—Wisconsin Section, at Hotel Schroeder, Milwaukee. Secretary, Harry Breimeister, Chief Utility Engr., City Engineer's Office, City Hall, Milwaukee 2.

Sep. 11–13—New York Section, at Saranac Inn, Upper Saranac Lake. Secretary, Kimball Blanchard, New York Branch Mgr., Rensselaer Valve Co., c/o Ludlow Valve Co., 11 W. 42nd St., New York.

Sep. 18–20—Ohio Section, at Netherland Plaza Hotel, Cincinnati. Secretary, M. E. Druley, Dist. Mgr., Dayton Power & Light Co., Wilmington.

Sep. 23–25—Kentucky-Tennessee Section, at Brown Hotel, Louisville, Ky. Secretary, J. Wiley Finney Jr., Howard K. Bell, Cons. Engrs., 553 S. Limestone St., Lexington, Ky.

Sep. 24–25—Rocky Mountain Section, at La Fonda Hotel, Santa Fe, N.M. Secretary, J. W. Davis, 301 Continental Oil Bldg., Denver 2, Colo.

Sep. 25–27—Michigan Section, at Leland Hotel, Detroit. Secretary, T. L. Vander Velde, Chief, Sec. of Water Supply, State Dept. of Health, Lansing 4.

Sep. 25–27—North Central Section, at Gardner Hotel, Fargo, N.D. Secretary, L. N. Thompson, 216 Court House Bldg., St. Paul 2, Minn.

Sep. 29–Oct. 1—Missouri Section, at Sheraton-Jefferson Hotel, St. Louis. Secretary, W. A. Kramer, State Office Bldg., Jefferson City.

Oct. 13–16—Southwest Section, at Skirvin Hotel, Oklahoma City, Okla. Secretary, Leslie A. Jackson, Mgr.-Engr., Water Works, Robinson Memorial Auditorium, Little Rock, Ark.

Oct. 16–18—Iowa Section, at Fort Des Moines Hotel, Des Moines. Secretary, J. J. Hail, Supt., Water Dept., City Hall, Dubuque.

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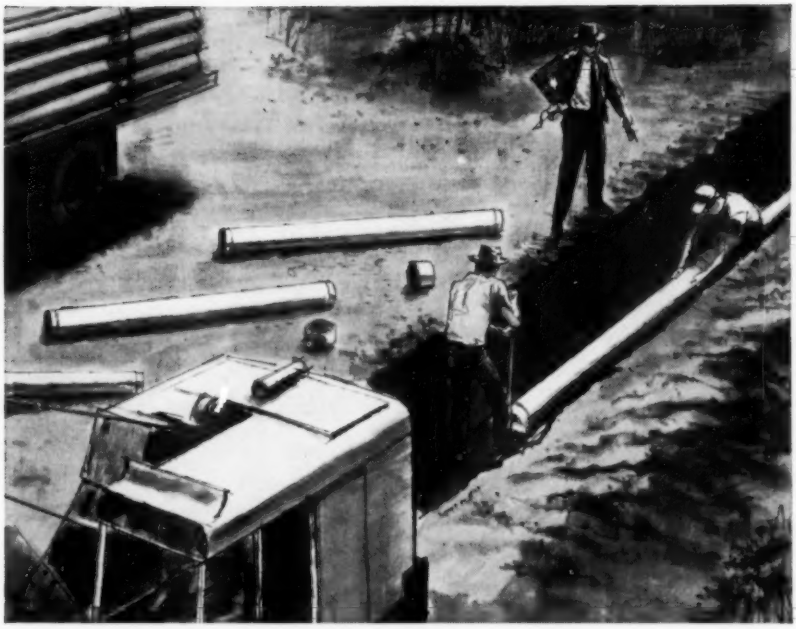

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Coming Meetings

(Continued from page 6)

Oct. 17–18—Canadian Section, Maritime Branch, at Nova Scotian Hotel, Halifax, N.S. Secretary, J. D. Kline, Asst. Mgr. & Chief Engr., Public Service Com., 162 Lady Hammond Rd., Halifax, N.S.

Oct. 20–23—Alabama-Mississippi Section, at Buena Vista Hotel, Biloxi, Miss. Secretary, C. M. Mathews, Public Service Com., 119 W. Commercial St., Yazoo City, Miss.

Oct. 23–24—West Virginia Section, at McClure Hotel, Wheeling. Secretary, H. W. Hetzer, Engr., West Virginia Water Service Co., Box 1906, Charleston 27.

Oct. 24–26—New Jersey Section, at Hotel Madison, Atlantic City. Secretary, A. F. Pleibel, Dist. Sales Manager, R. D. Wood Co., 683 Prospect St., Maplewood.

Oct. 29–Nov. 1—California Section, at Hotel St. Claire, San Jose. Secretary, Henry J. Ongerth, Sr. San. Engr., Bureau of San. Eng., 2151 Berkeley Way, Berkeley.

Oct. 30–Nov. 1—Chesapeake Section, at Sheraton-Park Hotel, Washington, D.C. Secretary, C. J. Lauter, 6955—33rd St., N.W., Washington, D.C.

Nov. 6–8—Virginia Section, at Hotel Roanoke, Roanoke. Secretary, J. P. Kavanagh, Dist. Mgr., Wallace & Tiernan Inc., 213 Carlton Terrace Bldg., Roanoke.

Nov. 10–13—Florida Section, at Roosevelt Hotel, Jacksonville. Secretary, J. D. Roth, P.O. Bin "O," Miami Beach 39.

Nov. 11–13—North Carolina Section, at Hotel Sir Walter, Raleigh. Secretary, W. E. Long Jr., State Stream Sanitation Com., Raleigh.

OTHER ORGANIZATIONS

Aug. 19–23—North Carolina Water Works Operators School, at Duke Univ., Durham, N.C.

Aug. 26–28—Hydraulics Div., American Society of Civil Engineers, at Kresge Auditorium, Massachusetts Inst. of Technology, Cambridge, Mass.

Sep. 9–13—Annual Instrument-Automation Conference & Exhibit, Instrument Society of America, Cleveland Auditorium, Cleveland, Ohio. Write: H. S. Kindler, Director of Technical Programs, Instrument Society of America, 313—6th Ave., Pittsburgh 22, Pa.

Oct. 6–9—Annual Conference & Products Exhibit, National Institute of Governmental Purchasing, at Netherland Hilton Hotel, Cincinnati, Ohio. Write: Albert H. Hall, Exec. Vice-Pres., 1001 Connecticut Ave., N.W., Washington 6, D.C.

Oct. 7–10—Federation of Sewage & Industrial Wastes Assns., at Statler Hotel, Boston, Mass.

Nov. 2–8—World Metallurgical Congress, sponsored by American Society for Metals, at Chicago, Ill.

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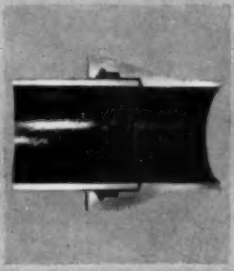

Result—a safe, economical joint with a tight, permanent seal.

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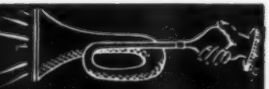

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(POWDER)

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(POWDER)

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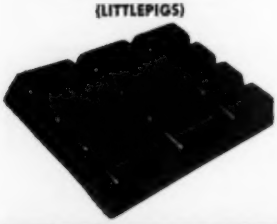
HYDRO-TITE
(LITTLEPIGS)



HYDRO-TITE

(LITTLEPIGS)

The same dependable compound in solid form —packed in 50 lb. cartons—2 litters of pigs to the box—24 easy-to-handle Littlepigs. Easier to ship, handle and store.

FIBREX
(REELS)

FIBREX

(REELS)

The sanitary, bacteria-free joint packing. Easier to use than jute and costs about half as much. Insures sterile mains and tight joints.

HYDRO-TITE

HYDRAULIC DEVELOPMENT CORPORATION

Main Sales Office 30 Church Street, New York Factory Office and Warehouse W. Medford Station Boston, Mass.

CLEAR CHOICE in Coagulants

GENERAL CHEMICAL Alum

Fact: most water and sewage treatment officials prefer General Chemical Aluminum Sulfate. *Reason:* they know they can depend on General Chemical for alum of unvarying quality and uniformity . . . for prompt, on-the-dot delivery.

There are 25 General Chemical producing works strategically located across the country to assure you of dependable service anywhere, anytime! Even in emergencies, *you can always count on General.*

CLEAR CHOICE FOR WATER TREATMENT

- Produces crystal clear water
- Gives better floc formation
- Promotes better settling and longer filter runs
- Aids in reduction of tastes and odors
- Has no chlorine demand
- Is a low-cost coagulant
- Superior in tests against other coagulants
- High in quality, its constant uniformity can be depended upon

CLEAR CHOICE FOR SEWAGE TREATMENT

- Clean, easy to handle
- Dry feeds well or dissolves readily for solution feeding; liquid alum also available in many areas
- Clear, colorless effluents are possible
- Simple application. Requires only low-cost feeding apparatus and minimum attention
- Sludge digests readily
- Treated digested sludge dries quickly with a minimum of odor
- Chlorine consumption is cut, due to lower demand of clarified sewage
- Economical to use

Basic Chemicals for American Industry

Allied Chemical

GENERAL CHEMICAL DIVISION

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Offices: Albany • Atlanta • Baltimore • Birmingham • Boston • Bridgeport • Buffalo • Charlotte • Chicago Cleveland • Denver • Detroit • Houston • Jacksonville • Kalamazoo • Los Angeles • Milwaukee • Minneapolis New York • Philadelphia • Pittsburgh • Providence • St. Louis • San Francisco • Seattle • Kennewick and Yakima (Washington). In Canada: The Nichols Chemical Company, Limited • Montreal • Toronto • Vancouver

You save money all along the line when you specify low-cost, long-lasting Concrete Pressure Pipe for your city's water supply, transmission and distribution mains. *In the main — the trend is to concrete* — because only dependable, economical Concrete Pressure Pipe gives you these important, money-saving advantages.

1

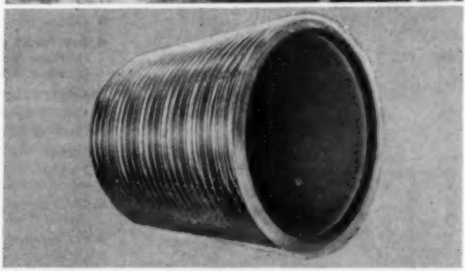
SAVE ON FIRST COSTS — The variety of designs available in concrete pressure pipe makes it possible to choose the most economical design which will serve with maximum efficiency under the specified operating conditions required of the line.

2

SAVE ON INSTALLATION COSTS — The joints of concrete pressure pipe are simply and rapidly installed. Since they require no welding, bolting or caulking, the trench width can be held to a minimum. Their dependability is such that the pipe may be backfilled almost immediately, eliminating the expense of open ditch maintenance.

3

SAVE ON MAINTENANCE COSTS — Since concrete pressure pipe is virtually impervious to corrosion, and since the careful design of the steel reinforcing makes the chance of bursting extremely remote, water works officials are able to point to the concrete pressure lines in their systems as the most economical to maintain.



4

SAVE ON PUMPING COSTS — Because of its extreme resistance to corrosion and tuberculation, the high initial carrying capacity of concrete pressure pipe will normally remain unimpaired throughout its unusually long life span. Resultantly, there will be no spiralling pumping costs through deterioration of the pipe's inner surface.

How your city can have

4 WAY SAVINGS

with Concrete Pressure Pipe!

TO SAVE MONEY FOR YOUR CITY,

SEND FOR FREE BOOKLETS

To find out how your Water Department can give your city the "4 big savings" built into every piece of Concrete Pressure Pipe, send today for free booklets. Requests handled promptly. Mail coupon today.

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Member companies manufacture concrete pressure pipe in accordance with nationally recognized specifications.

American Concrete Pressure Pipe Association
228 North LaSalle Street
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Gentlemen:
Please send me at no cost your literature on the subject: How Concrete Pressure Pipe Saves Money for Growing Cities.

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COMPANY _____

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CITY _____ STATE _____

How to Choose Waterstop for optimum performance in concrete joints

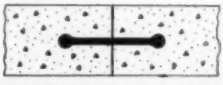
Basic Design And Resilience Most Important Factors

The principal function of waterstop is to keep concrete joints watertight where hydrostatic water pressure is present. To be effective, and to perform its function under widely varying conditions, the waterstop must:

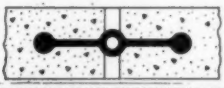
1. **Be designed in such a way that it will maintain a "pressure seal" when the joint is opened up or compressed, or when hydrostatic pressure is exerted against it.**

2. **Be made of a material that is inherently stable and resilient . . . that will retain its resiliency and strength under wide ranges of temperature.**

There is general agreement by many governmental and private specifying authorities, after years of testing and actual installation, that the dumbbell design of waterstop (below) is mechanically superior to any which has been developed to date. The design provides a self-sealing action, because as the concrete contracts and the joint opens up, the outer edges of the dumbbell bulbs become more tightly engaged with the concrete, insuring a tighter seal as the tension increases, due to movement either in the joint or increasing water pressure on one side of the joint. In effect, the greater the longitudinal pull or pressure on one side, the more tightly the dumbbell ends are pulled and squeezed against the concrete. The simpler dumbbell design of the rubber waterstop allows full strength and contact with the concrete surrounding the waterstop. The larger design also provides for maximum strength to resist higher pressures on the web of the waterstop across the joint opening.



6" DUMBBELL TYPE EMBEDDED IN CONCRETE WITH A CONSTRUCTION JOINT



9" HOLLOW BULB TYPE EMBEDDED IN CONCRETE WITH AN EXPANSION JOINT

Rubber and vinyl are the most commonly used waterstop materials. For the majority of applications, rubber is the most satisfactory material. Being a thermosetting material, rubber is more resilient and "live" . . . will maintain a constant pull against the retaining edges (bulbs) as the joint opens up or water pressure increases. Vinyl is a thermoplastic compound and tends to take a "set" after it has been stretched, will float in the joint cavity, and have less resistance to the passage of water. When higher temperatures are present, such as in oil storage tanks, where oil is kept at temperatures around 150°F., the vinyl material, unless specifications are rigidly written, will soften and lose strength, causing a failure of the waterstop.

Field Splicing of Dumbbell Type

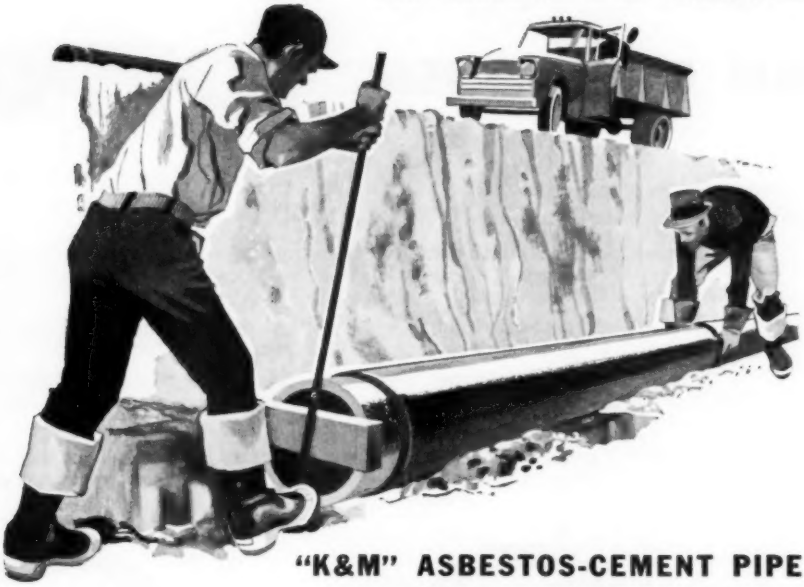
Servicised Products Corporation has developed a new Union which provides a simple method of joining the ends of dumbbell waterstops, making it just as fast and easy to field splice rubber and neoprene waterstop as the joining of the polyvinylchloride types.

The Union is made in the same cross-section, and from the same material as the waterstop. It is hollow, except for a solid web at the center. After adhesive is applied to the waterstop ends, they are inserted in the Union and pushed against the centering web. The splice is then clamped together until the adhesive has set. This completes the splice.

Dumbbell type rubber and neoprene waterstop are fully described in a special Waterstop Circular available from Servicised Products Corporation upon request. The Union and an interesting new development, Split Type, are also illustrated and described in the circular. Write for it today.

SERVICISED PRODUCTS CORPORATION
6051 W. 65th Street, Chicago 38, Illinois

THE MODERN PIPE JOINS TIGHT IN RAIN OR SHINE



"K&M" ASBESTOS-CEMENT PIPE and exclusive FLUID-TITE Coupling

No need to wait for dry skies or a dry trench before installing "K&M" Asbestos-Cement Pipe. Wherever water is to be piped under pressure, "K&M" Pipe is the modern answer. The exclusive FLUID-TITE® Coupling makes installation quick, easy—and permanent.

No special equipment; little skill needed. Just two easy steps: 1. Lubricate rubber rings; 2. Slide pipe into coupling. It is watertight immediately. The FLUID-TITE Coupling allows deflection up to 5° at each joint. Installation and maintenance costs go down when you specify the *modern* pipe and coupling . . . "K&M."

Meets specifications. "K&M" Pressure Pipe meets A.W.W.A., A.S.T.M., and U.S. Federal Specifications, and has Underwriters' Laboratories approval for all sizes (pipe and couplings) in Class 150.

Learn the advantages of the *modern* pipe from the K&M distributor. Or write to us for complete information, including a Flow Chart for "K&M" Pipe based on the Williams and Hazen formula.

Exclusive sealing rings are the secret of the "K&M" FLUID-TITE Coupling installed with "K&M" Asbestos Pipe. All "K&M" couplings and pipe are hydrostatic pressure-tested to 3½ times the rated operating pressure!

KEASBEY & MATTISON
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K·M BEST IN ASBESTOS

Protect YOU

USE MUELLER COPPER

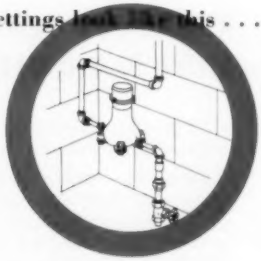
Mueller Copper Meter Yokes give strong, permanent settings for your water meters quickly and easily. Installation time is reduced to a minimum and fittings are practically eliminated.

Ribbed body absorbs piping stresses without transmitting them to the meter. Meters are protected to insure accurate measurement and full revenue.

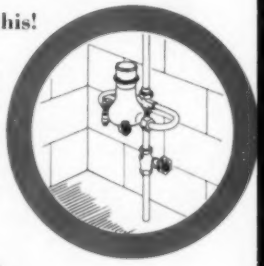
Properly spaced and aligned swivel nuts make meter changes for testing and maintenance a cinch. Pipes are not disturbed and replacement is fast and easy. Swivel nuts are drilled for wire seal, too.

And Mueller's special, multi-purpose end connections give you a choice of outside I.P., inside I.P., copper or any combination of these connections just by changing tail-pieces.

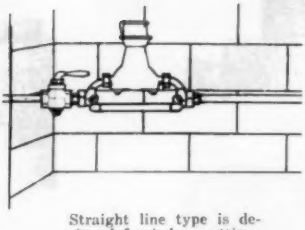
If your meter settings look like this . . . . . try this!



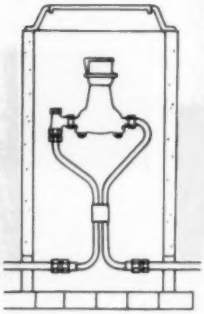
Save time, fittings and pipe in basement meter settings by installing a Mueller Copper Meter Yoke specifically designed for basement settings. A tailor-made setting for your meter at right angles to the service line is quickly completed.



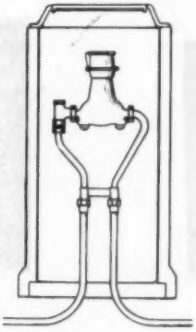
a* COPPER *Meter Yoke for any installation!



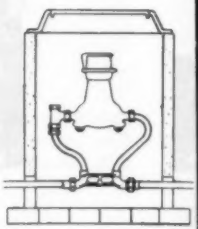
Straight line type is designed for indoor settings where meter cannot be raised or for outdoor use with shallow lines.



Flexible inlet and outlet of this yoke make it easy to install where pipes are out of line and connections are difficult to make. Also available for pipes at different levels, for angle settings or extended for connections outside of box.



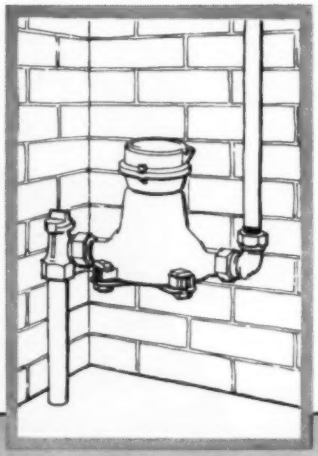
Vertical inlet and outlet type makes it possible to use regular outdoor meter box for deeply-buried lines.



Horizontal inlet and outlet type is used for outdoor meter box settings where service line is buried at medium depth.

WATER METERS...

METER YOKES!



And if you cannot use a meter yoke . . . use a

MUELLER *Angle Meter Stop!*

An ideal setting for extremely confined locations where there is not enough space for a yoke or stop, is a Mueller Angle Meter Stop and Meter Coupling. Setting is made quickly and no other fittings are needed.

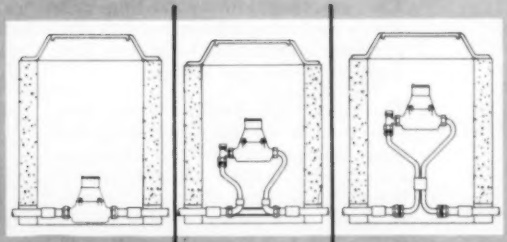
Install Copper Meter Yokes in your existing services without changing piping or fittings!

Mueller Copper Meter Relocater Yokes are easily installed in place of present meters without disturbing original fittings or piping in any way.

Yoke body is the same length as meter and inlet and outlet connections have standard meter spud threads. Meter is raised above dirt and water in meter box and made much easier to read or change. And flat head or lock wing stop may be included right in the yoke.

Flexible Copper Meter Relocaters make it easy to raise meters even when pipe has shifted out of line or moved closer together or farther apart. The flexibility of the connections is not transmitted to the upper portion of the yoke and spacing for meter is unaffected.

. . . see your Mueller Representative today!



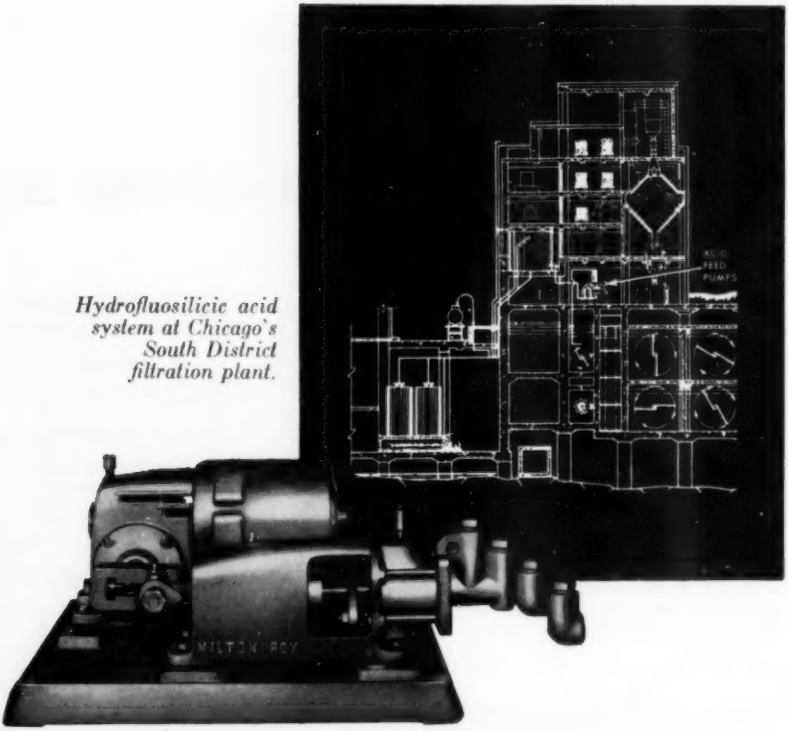
Original installation | Relocater Yoke | Flexible Relocater

Since 1857

MUELLER CO.

DECATUR, ILL.

Factories at Decatur, Chattanooga, Los Angeles; In Canada: Mueller, Limited, Sarnia, Ontario



Hydrofluosilicic acid system at Chicago's South District filtration plant.

Controlled Volume Pumps feed fluorides to Chicago's water

Every day, 1400 gallons of 23% hydrofluosilicic acid are added to 340,000,000 gallons of water at Chicago's South District filtration plant. The exacting job of feeding this highly corrosive acid in correct proportions is entrusted to Milton Roy Controlled Volume Pumps.

The Controlled Volume Pump system consists of three direct-displacement pumps, powered by one electric motor through variable speed transmission. One pump serves each of three acid mixing basins. Each pump has a maximum capacity of 43 gallons per hour.

In any water treating job, Milton Roy Controlled Volume Pumps provide the logical, economical answer to accurate flow control and chemical metering. Write for technical information. Milton Roy Company, *Manufacturing Engineers*, 1300 East Mermaid Lane, Philadelphia 18, Pa.

milton Roy
CHEMICAL FEED SYSTEMS

Engineering Representatives in the United States, Canada, Mexico, Europe, Asia, South America ,Africa and Australia.

Untried!

Diatomite "untried" for water filtration?

Come, come now!

In a recent article in a waterworks publication* there were accounts of 25 municipal diatomite filtration plants operating in the United States, 22 of them with the approval of State health departments. These plants are located in New York, Michigan, Minnesota, Virginia, New Mexico and Oregon... they draw their raw water from rivers, reservoirs, lakes, brooks and an aqueduct... they use diatomite filtration for the removal of turbidity, algae, plankton, iron, manganese and color. (Incidentally, several of those longest in operation and most successful in results use Dicalite Filteraids.)

Of the 21 plants reporting operating results, 8 said 'good to excellent'; 11 reported 'satisfactory'; 1 'fairly good,' and only 1 reported 'problems'—these due to excessive organisms in the raw water.

While the author's discussion indicates his feeling that existing plant practices could be improved in most cases, his conclusion was unqualified: DIATOMITE FILTRATION OF MUNICIPAL WATER SUPPLY CAN BE BOTH SUCCESSFUL AND ECONOMICAL!

* *A reprint of this important article is available on request from*

Dependable GLC GREAT LAKES Dicalite® DIATOMACEOUS MATERIALS

DICALITE DEPARTMENT
Great Lakes Carbon Corp.
612 S. Flower St.
Los Angeles 17, Calif.

E. R. P. CATHODIC PROTECTION . . .

individually designed for each application

An effective installation that operates at the lowest cost per year requires experienced engineering evaluation of site and environmental conditions. The Electro Rust-Proofing Engineering Division makes available to you the cumulative experience gained in designing more than 10,000 cathodic protection systems.

Electro Rust-Proofing can furnish any one, or all, of the following services to help you provide proper cathodic protection for each of your jobs:

- Corrosion surveys and recommendations
- Design based on engineering experience
- Cathodic protection equipment and installation
- Service to assure proper operating results

For additional information write today.

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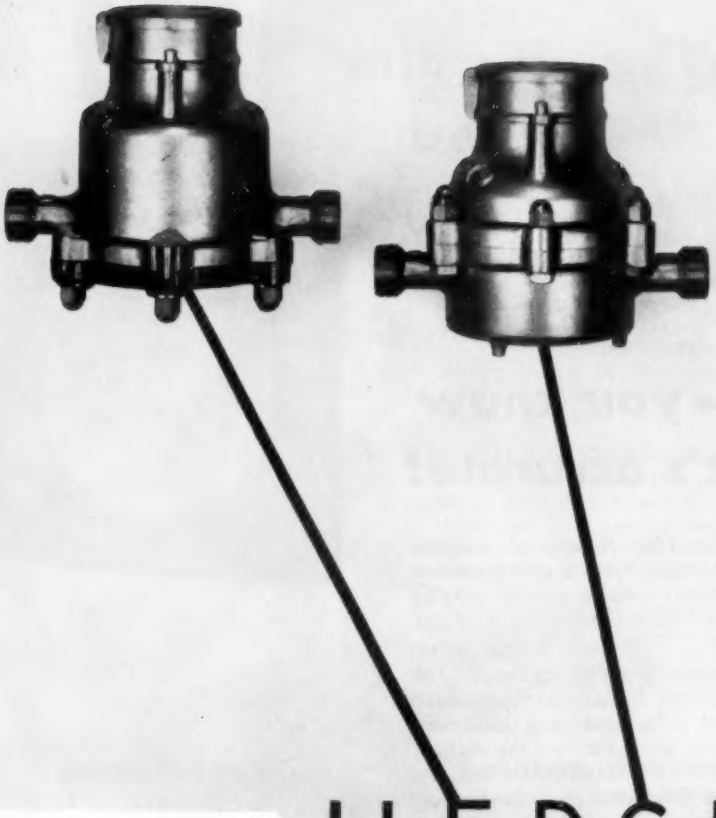


When the name HERSEY

is on a WATER METER it assures you of the

meter service with the lowest maintenance cost

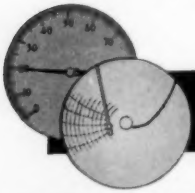
HERSEY MANUFACTURING COMPANY
SOUTH BOSTON, MASS.
BRANCH OFFICES: NEW YORK — PORTLAND, ORE. — PHILADELPHIA — ATLANTA — DALLAS
CHICAGO — SAN FRANCISCO — LOS ANGELES

When it's B/M "Matched Metering"

—you know it's accurate!

The high fidelity of Burgess-Manning Electric and Electronic Meters is made possible only by the Burgess-Manning null-balance inductance bridge, servo-powered meter principle employed. To this has been added the refinement of a calibrated cam, which matches the calibration of the recorder-totalizer and the differential producer for perfection thru "Matched Metering". Burgess-Manning electric transmission is suitable for distances up to 5000 feet. You'll never regret having specified Burgess-Manning "Matched Metering" for greatest overall accuracy. Request Catalog 800.

Burgess-Manning Meters are also available in mechanical types.

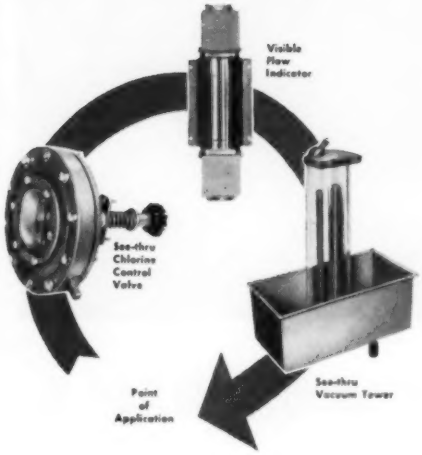


BURGESS-MANNING COMPANY
PENN INSTRUMENTS DIVISION
4124 Haverford Ave., Philadelphia 4, Pennsylvania

Instrumentation and Controls for water, steam, gases, sewage and industrial wastes

FVVF *

***FVVF means Full Vision Vacuum Feed,** that extra margin of safety so vital when handling chlorine gas. Protect both personnel and plant equipment with Builders Chlorinizer. Get FVVF . . . plus the shortest gas flow path design offered by any manufacturer . . . for the SAFEST chlorination available.



Model EVS Chlorinizer offers FVVF with "see-thru" components that give *visual proof of operation* and *positive evidence of effective vacuum.* Low initial cost results from design simplicity. Eye-level Sightflo Indicator (with wide range, linear scale) provides *easy, accurate reading and setting of feed rate.* Available in 11 standard RATE capacities ranging from 4 to 400 lbs. of chlorine per 24 hrs.

Check These Other Features

- Easy Installation
- Automatic Safety Features
- Low Maintenance
- No Chlorine "Ice" Problems
- No Tray Odors
- 8 to 1 Metering Range
- Accurate within ±4% of actual feed rate
- Money-back performance guarantee!!

Act Today!

Request Bulletin 840-L23A.
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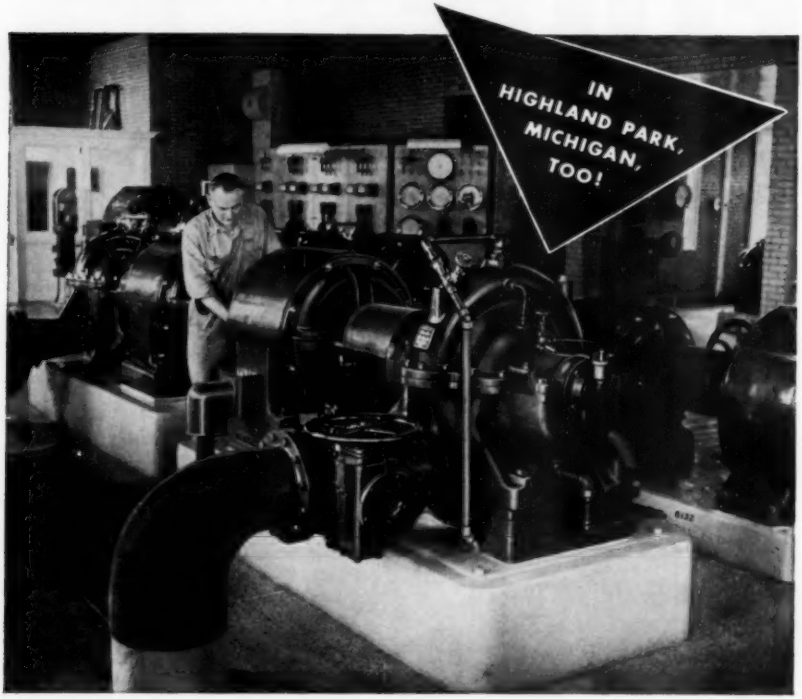
DIVISION OF
B-I-F INDUSTRIES
B·I·F METERS FEEDERS CONTROLS

DE LAVAL pumps America's water . . .



The photograph shows a De Laval centrifugal pump on line at the Davison and Dequindre pumping station of the Highland Park, Michigan Water Works. The Highland Park Water Works has eight De Laval motor driven units, with a total capacity of over 50 million gallons per day in service at the above station and at their high lift station on Lake St. Clair, which pumps raw water 11.6 miles to their purification plant. According to the user, all eight pumps have given excellent performance in year-round service.

Write for your copy of new De Laval Bulletins 1004 and 1005 giving data on these pumps.

MR. T. L. DUNKIRK
City Engineer

MR. V. L. HINEBROOK
Superintendent of Water Department

MR. W. L. WELTER
Asst. Superintendent Water Department

DE LAVAL *Centrifugal Pumps*

DE LAVAL STEAM TURBINE COMPANY
822 Nottingham Way, Trenton 2, New Jersey

DL3982A

FOR THE BEST IN *Water Meters*

go

ALL AMERICAN

AMERICAN METERS

Operate Silently

The whisper-quiet performance of American Meters is an achievement of American Advanced Engineering. Metal-to-metal clicking noises that originate in the measuring chamber and delicate parts that set up vibrations have been eliminated. Precision-fitted bearings of hard rubber reduce noise. All are the result of more than 63 years of meter-building experience. The silent operation of American Meters builds solid customer satisfaction, especially where meters are installed in utility rooms of compact modern homes.

If you would like to avoid headaches that arise from troublesome nuisance calls about noisy meters—"go all AMERICAN!"

BUFFALO METER CO. 2914 MAIN STREET BUFFALO 14, N. Y.

Call on Eddy for whatever you need in the way of fire hydrants—or for valves and accessories for water, oil or gas . . . standard or special applications. Replacement parts always available—proof you can always

depend on

EDDY VALVE COMPANY
A subsidiary of James B. Clow & Sons, Inc.

WATERFORD, NEW YORK

Armco Pipe Takes Rugged Terrain in Stride

Nearly two miles of Armco Pipe in 18- and 24-inch diameters, .250-inch wall thickness, supply water to the Borough of North East, Pennsylvania. The ductile steel pipe and mechanical joints adjust to the hilly contour of the land.

You don't have to worry about laying a water line over rough territory when you use Armco Welded Steel Pipe. Armco Pipe is strong yet ductile enough to take hills, curves, stream crossings, and other obstructions in stride. This strength and ductility also mean that your water line can withstand unstable foundations and shifting loads.

Armco Pipe is supplied in diameters from 6 to 36 inches and wall thicknesses from $\frac{9}{64}$- to $\frac{1}{2}$-inch. You can save money by getting exactly the size you need to do the job. No need to compromise on the "next largest size."

Armco also supplies a wide variety of gates for water treatment plants. Write to us for complete information applied to your specific needs. Armco Drainage & Metal Products, Inc., 3617 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation. In Canada: Write: Guelph, Ontario.

Armco Welded Steel Pipe

ARMCO®

DELIVERING WATER CHEAPER

The high beam strength of steel pipe plus the adaptability of Dresser Couplings makes them the ideal combination for irregular terrain.

Four-man crew using power wrenches assembles this Dresser Coupling in minutes. Dresser Couplings tested bottle-tight on line pressures up to 800 psi.

54 Miles of 30″ Dresser-Coupled Steel Pipe Installed in 68 Days at Colorado Springs!

Water supply problems are nothing new to Colorado Springs. Back in 1924, the city constructed a steel pipe line to collect runoff from the south slope of Pikes Peak. That line has been giving dependable, trouble-free service ever since, so it was experience plus good engineering judgment that led to the choice of steel pipe with Dresser Couplings for the city's latest 54-mile addition to its water supply system.

The new 30″ line runs from Montgomery Dam to Lake George — over some very rugged terrain — to deliver 18 mgd to Colorado Springs and to help supply the new U.S. Air Force Academy nearby.

Here's how Dresser Couplings helped make it possible to install this 54-mile line in 68 working days: A four-man crew, using power wrenches, assembled the Dresser Couplings on the pipe . . . some in as little as two minutes. Next, a two-man crew pulled the coupling bolts up to proper torque. The line was laid *at the average rate of about 4,200 ft. per day.*

For a bottle-tight, trouble-free line that *delivers water cheaper,* it pays to specify steel pipe with Dresser Couplings. Dresser Manufacturing Division, Bradford, Pennsylvania.

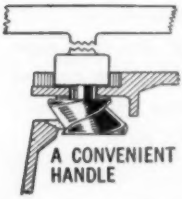
ONE OF THE DRESSER INDUSTRIES

Why BREAK YOUR BACK?

When the Ford Lifter Worm Lock is so easy to use

A STRONG LOCK

A POWERFUL SCREW-JACK



A CONVENIENT HANDLE

Snow, ice and dirt tending to hold down meter box lids are easily conquered with the Ford Lifter Worm Lock.

This simple mechanism, operating like an auto-jack, has a tremendous lifting force that breaks any seal around the edges of your covers.

It's handy, too, because it locks and unlocks your lid to prevent tampering. It offers extra safety because an unlocked lid is detected at a glance.

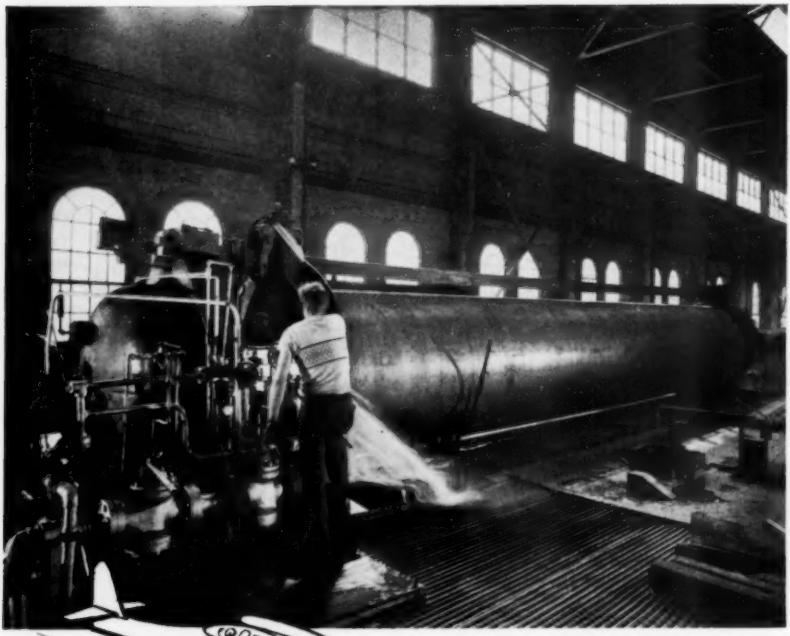
The key which operates the Lifter Worm Lock serves as a handle to lift the lid, saving time and keeping hands clean.

Send for complete data and Free Catalog.

THE FORD METER BOX COMPANY, INC.
WABASH, INDIANA

FOR BETTER WATER SERVICES

FORD



STEEL PIPE
HAS ITS TEST PILOTS, TOO!

Like the more glamorous aviation test pilot, the steel pipe tester plays a vital role in the story of safety. His job demands the greatest caution and concern to assure your water pipe meeting the highest standards of safety, strength and performance.

This specialist hydrostatically tests *every* length of steel pipe to at least twice its required working pressure . . . to guarantee you maximum protection against breakage and leakage. And steel pipe is the *only* water pipe that undergoes this rigid individual testing process.

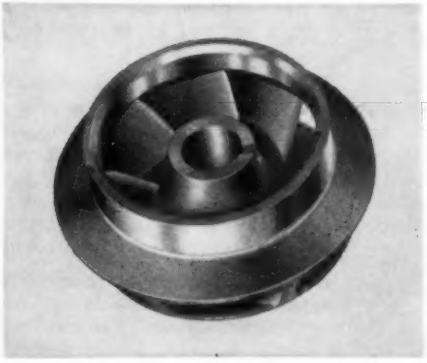
When you need a pipe that you know in advance will pass all the tests of stress and time—you're smart to specify STEEL pipe.

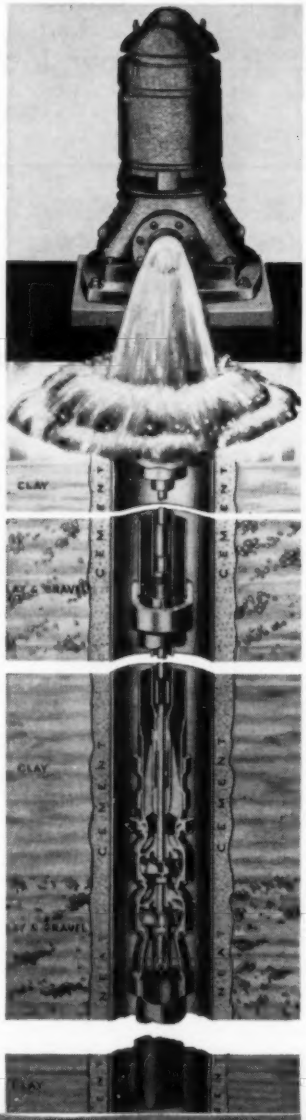
"WHEREVER WATER FLOWS—STEEL PIPES IT BEST"

STEEL PLATE FABRICATORS ASSOCIATION

79 W. MONROE ST., CHICAGO 3, ILL.

Deep in the Earth There's Another Reason Layne's on Top!





The Layne impeller is that reason, because a pump can be no better than its impeller.

Each Layne impeller is precision manufactured. Both hand finishing and special machining are used in balancing and tooling the impeller. The result—an impeller dynamically in balance which operates deep in the recesses of the earth. Each remaining component part receives the same careful engineered attention which assures you years of trouble-free operation and performance.

LAYNE'S 75 YEARS OF EXPERIENCE PUTS LAYNE ON TOP!

1882 — 1957
Layne
75 YEARS OF PROGRESS

WATER WELLS • VERTICAL TURBINE PUMPS • WATER TREATMENT

LAYNE & BOWLER, INC. MEMPHIS

General Offices and Factory • Memphis 8, Tennessee

LAYNE ASSOCIATE COMPANIES THROUGHOUT THE WORLD

How long before you install water softeners?

A month? . . . A year? . . . Or do you already have this equipment? In any event, this article can help you use water-softening salt with maximum efficiency. This is number 6 in a series prepared by International Salt Company.

How to Store Large Tonnages of Rock Salt in Limited Space

One of the best ways to increase salt-storage capacity, without taking up valuable space near your water-softening installation, is to use a "Silo Lixator." Developed by International, this space-saving unit actually *combines* salt-storage with brine-making—and maintains a ready supply of fully saturated brine for regenerating zeolite and/or base-exchange resins.

The Silo Lixator makes excellent use of limited storage space, because it stores rock salt in a high, vertical column. The upper portion of the column stores dry salt. The bottom of the column rests in a dissolving tank, where water is added to make brine. Whenever salt in this tank is dissolved, it is immediately replaced by dry salt flowing down from the upper portion of the column.

For storing any given amount of rock salt in dry form, ample space can be provided in the Silo portion, by building it to the proper height. The rugged steel, wood-stave, or prefabricated-concrete construction of the Silo assures long, dependable service.

Rehandling Eliminated. Because dry salt stored in the Silo Lixator is dissolved to make brine, there is never any salt rehandling in the plant. A simple piping system, installed where it won't interfere with other operations, carries this brine to points of use. What's more, every drop of Lixate Brine is completely self-filtered by the rock salt crystals at the bottom of the dissolving tank. So you always have clear, 100%-saturated brine—the brine that always gives you complete, economical zeolite regeneration.

Incoming salt shipments need no special handling. One of the more common delivery methods works like this: rock salt flows directly from a hopper car into a screw-conveyor trough, which, in turn, carries the salt to a bucket elevator. Another unloading method, possible when the elevator boot is low enough to permit gravity feed from the hopper car, is the gravity-feed chute.

Another money-saving feature: The Silo Lixator needs to be cleaned out only once every 12 to 18 months. The clean-out process is very simple: a valve or door is opened at the bottom of the dissolving compartment. All accumulated impurities are flushed through the clean-out, and the Silo Lixator is ready for use . . . needs no further attention for at least another year.

Salt—plus technical service—from International

Through skilled and experienced "Salt Specialists," we can help you get greater efficiency and economy from the salt or brine you use for regeneration. We produce both Sterling Evaporated and Sterling Rock Salt in all types and sizes. So we can recommend the type and size of salt most perfectly suited to your needs.

If you'd like to get this technical assistance —or any other information on salt or brine —simply contact your nearest International sales office: Atlanta, Ga.; Chicago, Ill.; New Orleans, La.; Baltimore, Md.; Boston, Mass.; Detroit, Mich.; St. Louis, Mo.; Newark, N.J.; Buffalo, N.Y.; New York, N.Y.; Cincinnati, O.; Cleveland, O.; Philadelphia, Pa.; and Richmond, Va.

INTERNATIONAL SALT CO., INC.

SCRANTON 2, PA.

How to select the right flow-measuring device

Selecting the correct device is simply a matter of choosing the one that best meets your requirements. The wide variety of Simplex Primary Elements makes this selection easy.

This table shows you which of Simplex's standard elements performs best under various flow conditions. (Not shown are Simplex primary devices of steel or concrete, designed to meet the physical limitations on special jobs.)

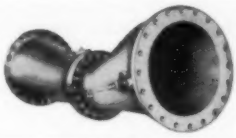
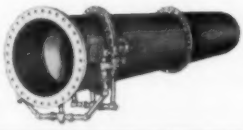
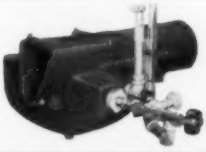
SIMPLEX VENTURI TUBES produce a minimum head loss—returning 85% to 90% of the differential head developed for meter operation. Since pressure differentials are measured between the main and throat sections, the tubes are smooth, true in shape and of accurate diameters to produce a stable coefficient of discharge. This gives you accuracy over wide flow ranges . . . accuracy within ±0.3% if required.

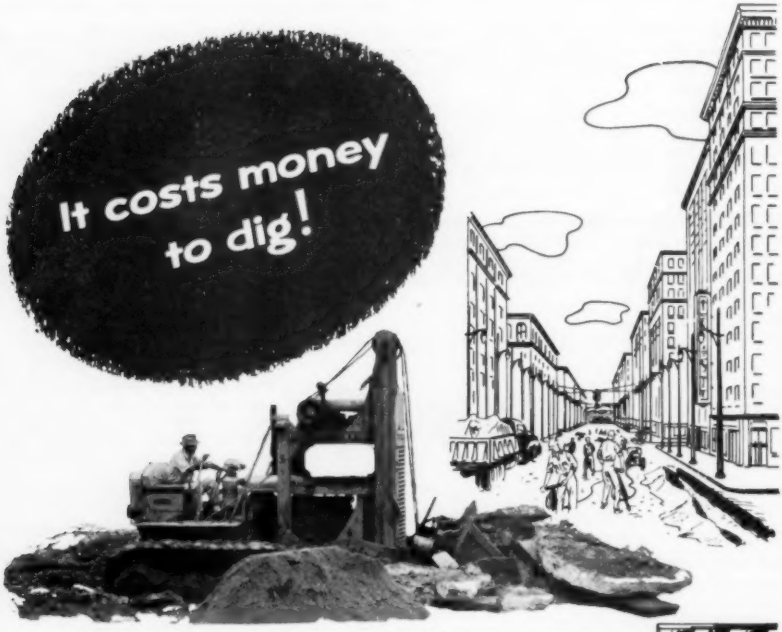
Write for Technical Bulletins. Simplex Valve & Meter Co., Dept. JA-8, 7 East Orange Street, Lancaster, Pa.

SIMPLEX®

VALVE AND METER COMPANY

VENTURI TUBES • FLUMES • METERS • GAUGES
TRANSMITTERS • CONTROLLERS • TABLES • AIR VALVES

FLOW CONDITION		SOLUTION
NORMAL WATER, AIR OR GAS FLOWS		TYPE VT—STANDARD VENTURI TUBES Cast iron with bronze bushed main piezometer holes and bronze throat liner. Flanged, bell or spigot ends. Inspection opening at throat. Special metals for high pressures or caustic liquors, corrosive gases, brines, etc. BULLETIN 005
NORMAL WATER, AIR OR GAS FLOWS		TYPE TG—INSERT TUBES AND NOZZLES Withstand high pressures. Fit inside existing lines . . . permitting light construction. This, plus *short length*, cuts costs. BULLETIN 100
SMALL FLOWS OF WATER, GASES CORROSIVE FLUIDS		TYPE TF—MINIATURE VENTURI TUBES Machining to .0005" assures accuracy. Main diameters as low as ½"; throat diameters down to .1". Welded stainless steel models for high pressures. BROCHURE
NORMAL SEWAGE, SLUDGE, TRADE WASTES		TYPE VTJ—SINGLE TAP VENTURI TUBES Single taps at main and throat have bayonet-type valve for fast cleaning. Absence of pressure belts prevents clogging. Inspection opening at throat. BULLETIN 005
NORMAL SEWAGE, SLUDGE, TRADE WASTES		TYPE VS—FOUR TAP VENTURI TUBES Four cleaning valves at main and throat can be operated manually, by air, or hydraulically to keep piezometer holes clear for top accuracy. Two hand holes on each pressure belt and inspection opening at throat. BULLETIN 005
LOW-VELOCITY SEWAGE, HEAVY WASTES		TYPE VE—ELLIPTICAL VENTURI TUBES Developed specifically to accurately measure low-velocity sewage, sludge and heavy trade wastes—under low pressures. *Flat top* prevents air binding. *Flat bottom* is self-scouring. Inspection opening at throat. BROCHURE
LOW-HEAD SEWAGE, SLUDGE, TRADE WASTES		TYPE S—PARABOLIC FLUMES Full 20:1 range for open flows. Accuracy ±2%. Flanged, bell or spigot inlet for 6 to 36" lines. Integral sediment trap, piezometer reamer, gauge glass, direct-reading flow scale. BULLETIN 801



Digging up city streets to replace worn-out mains is always a costly operation . . . and one that causes great public inconvenience.

Installation of permanent CAST IRON PIPE is the best insurance any community can buy against recurrent and costly outlays for pipe replacement and repairs. **No non-metallic substitute ever matched the record of CAST IRON PIPE for longevity, durability, dependability, low maintenance cost and long run economy.**

These 68 Cities in the U. S. A. and Canada are still using CAST IRON Water or Gas Mains laid more than a century ago:

ALBANY, *New York*
ALEXANDRIA, *Virginia*
ALLENTOWN, *Pennsylvania*
ATLANTA, *Georgia*
BALTIMORE, *Maryland*
BOSTON, *Massachusetts*
BOUND BROOK, *New Jersey*
BRIDGEPORT, *Connecticut*
BUFFALO, *New York*
CHARLESTON, *South Carolina*
CHICAGO, *Illinois*
CINCINNATI, *Ohio*
COLUMBIA, *Pennsylvania*
DETROIT, *Michigan*
ELIZABETH, *New Jersey*
EVANSVILLE, *Indiana*
FALL RIVER, *Massachusetts*
FREDERICK, *Maryland*
FREDERICKSBURG, *Virginia*
HALIFAX, *Nova Scotia*
HARTFORD, *Connecticut*
HUNTSVILLE, *Alabama*
INDIANAPOLIS, *Indiana*
KNOXVILLE, *Tennessee*
LANCASTER, *Pennsylvania*
LOUISVILLE, *Kentucky*
LYNCHBURG, *Virginia*
MADISON, *Indiana*
MEDIA, *Pennsylvania*
MINERSVILLE, *Pennsylvania*
MOBILE, *Alabama*
MONTREAL, *Quebec*
NASHUA, *New Hampshire*
NASHVILLE, *Tennessee*
NEW BRUNSWICK, *New Jersey*
NEW HAVEN, *Connecticut*
NEW ORLEANS, *Louisiana*
NEWARK, *New Jersey*
NEW YORK, *New York*
NORRISTOWN, *Pennsylvania*
PAINESVILLE, *Ohio*
PEORIA, *Illinois*
PHILADELPHIA, *Pennsylvania*
PITTSBURGH, *Pennsylvania*
PLYMOUTH, *Massachusetts*
POTTSVILLE, *Pennsylvania*
PROVIDENCE, *Rhode Island*
QUEBEC, *Canada*
READING, *Pennsylvania*
RICHMOND, *Virginia*
ROCHESTER, *New York*
SACRAMENTO, *California*
ST. JOHN, *New Brunswick*
ST. LOUIS, *Missouri*
SALEM, *Massachusetts*
SAVANNAH, *Georgia*
SPRINGFIELD, *Illinois*
SYRACUSE, *New York*
TORONTO, *Ontario*
TROY, *New York*
UTICA, *New York*
WHEELING, *West Virginia*
WILLIAMSPORT, *Pennsylvania*
WILMINGTON, *Delaware*
WINCHESTER, *Virginia*
WINSTON-SALEM, *North Carolina*
YORK, *Pennsylvania*
ZANESVILLE, *Ohio*

Our Company does not manufacture Cast Iron Pipe but supplies many of the nation's leading foundries with quality pig iron from which quality pipe is made.

WOODWARD IRON COMPANY
Since 1882
WOODWARD, ALABAMA

ANOTHER GRAVER ANSWER TO A WATER STORAGE PROBLEM

This 400,000 gallon elevated water tank for Plymouth, Indiana, is another example of Graver's skilled craftsmanship in steels and alloys. Graver's nationwide organization and 100 years of experience in the design, fabrication and erection of all types of storage tanks can be of valuable assistance in solving your water storage problems, too! Write today for information.

GRAVER TANK & MFG. CO., INC.

New York • Philadelphia • Edge Moor, Del. • **EAST CHICAGO, INDIANA**
Pittsburgh • Detroit • Chicago • Tulsa • Sand Springs, Okla.
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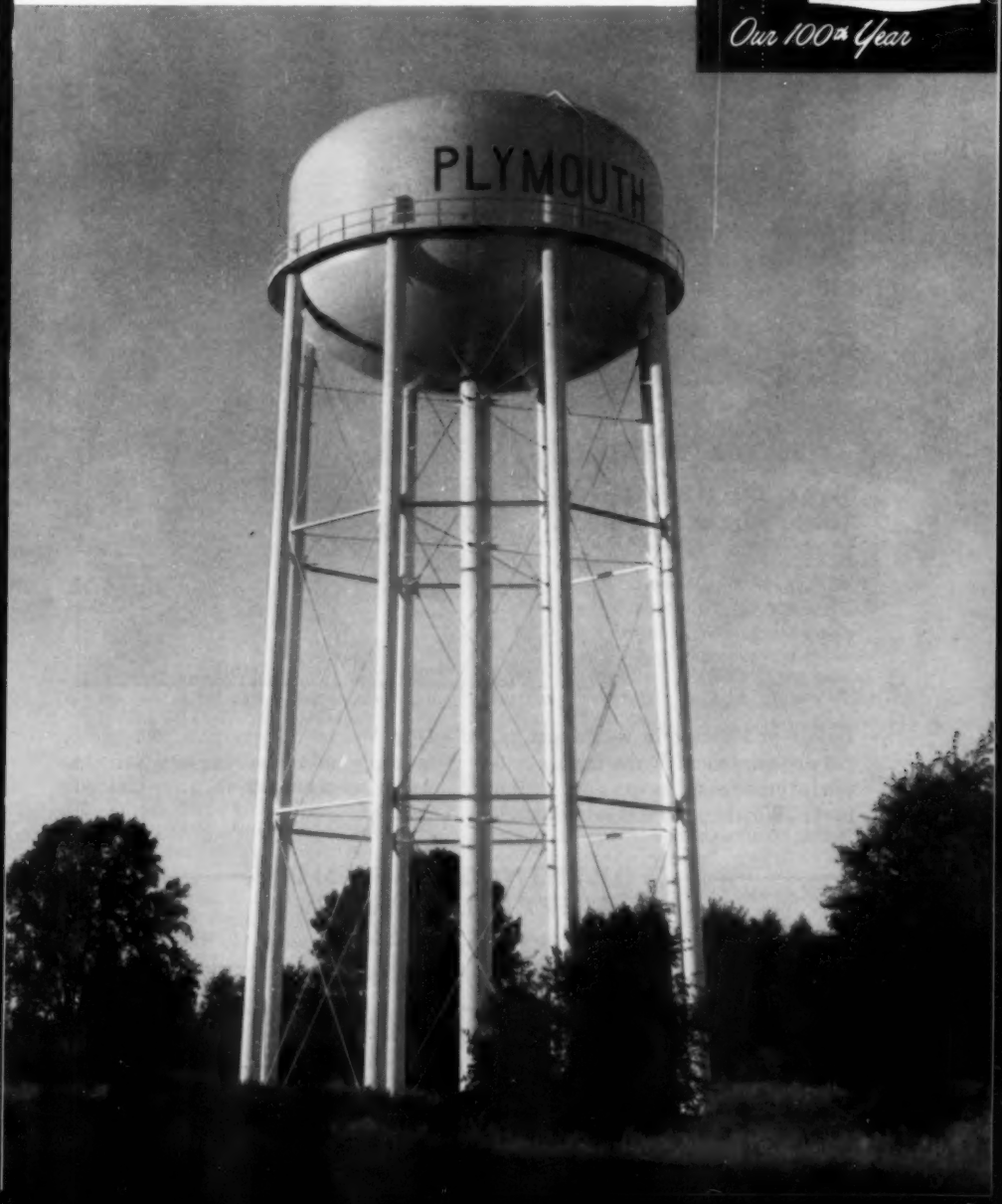
1857-1957 GRAVER® *Our 100th Year*



WORTHINGTON-GAMON

WATCH DOG

The meter used by thousands of municipalities in the U. S.

WATER METERS

"Watch Dog" models . . . made in standard capacities from 20 g.p.m. up: frost-proof and split case in household sizes. Disc, turbine, or compound type.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE.

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

WORTHINGTON-GAMON METER DIVISION

Worthington Corporation

296 SOUTH STREET, NEWARK 5, NEW JERSEY

OFFICES IN ALL PRINCIPAL CITIES

Mr. Evan Evans (right) and Mr. Clarence Dankel (left)

"Our 30-in steel pipe is going strong after 25 years"

(Report of an interview with Evan Evans, president, and Clarence Dankel, general manager, Panther Valley Water Company, Lansford, Pa. In 1932 this company constructed a 30-in.-ID steel pipe line nearly 10 miles from Still Creek dam to Coaldale. The pipe was fabricated in 30-ft lengths by Bethlehem Steel Company. It was lined with $\frac{3}{32}$-in.-thick Bitumastic enamel, and is thought to have been the country's first large steel water main to be enamel-lined centrifugally. Engineers were Gannett, Seelye & Fleming, now Gannett, Fleming, Corddry & Carpenter, Inc., Harrisburg, Pa.)

Q. Mr. Evans, is the Still Creek line in service today?

A. Yes, it's been used continuously since 1932, carrying about 15,000,000 g.p.d.

Q. How about the flow capacity?

A. The average "C" as determined by our flow tests in 1933 and in 1940 was about 145. I'd say that the flow capacity is just about as good as ever today, with no damage to the tar enamel lining as far as I know.

Q. Has the pipe ever failed in any way?

A. No, and it's quite amazing. During the flood caused by hurricane Connie in 1955 the cover was completely swept away from about 1000 ft of the pipe. In many places the pipe spanned 50 or 60 ft without any support whatsoever. Yet there wasn't even the trace of a failure. What's more, the line runs right through our worst areas of subsidence due to mine cave-ins. Still no trouble with the pipe.

Q. What kind of soil is the pipe laid in?

A. Just about the worst you could find. It's "hot" soil; lots of coal banks and the like. But it hasn't damaged the pipe.

Q. Then you're satisfied with performance of the line?

A. We're well pleased in every respect.

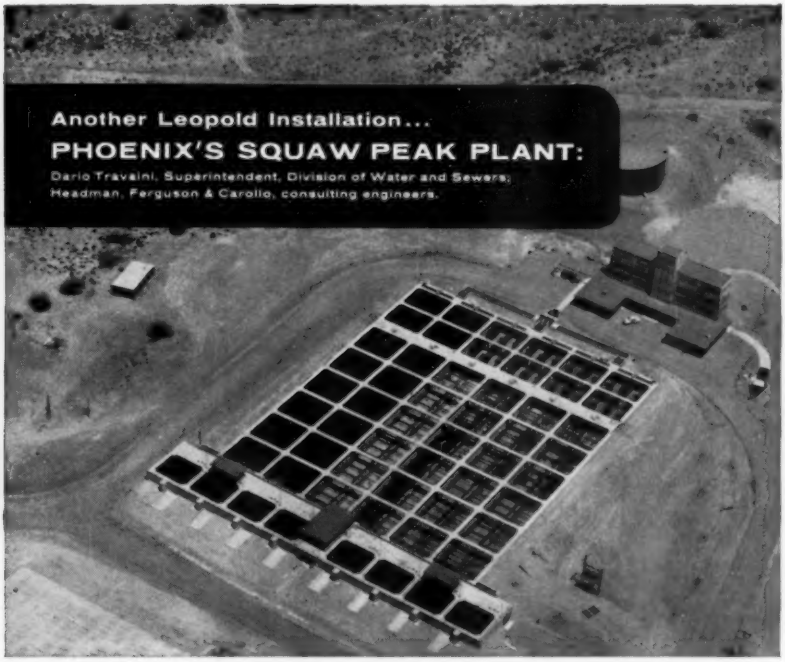
Would you like to have more information about Bethlehem Tar-Enameled Steel Pipe? Please contact the Bethlehem sales office most convenient to you.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL


Another Leopold Installation...
PHOENIX'S SQUAW PEAK PLANT:
Dario Travaini, Superintendent, Division of Water and Sewers;
Headman, Ferguson & Carollo, consulting engineers.

Second Water Filtration Plant for Phoenix, Arizona, also uses **LEOPOLD FILTER BOTTOMS**

To solve the problem of an unusually heavy summertime demand for water, the City of Phoenix constructed, and now has in operation, an additional 30-mgd water filtration plant. Located about ten miles north of the city, this Squaw Peak plant cost over 2¼ million dollars. Although it is presently used only during the summer months, it represents an important step in Phoenix's long range plan of water works improvement and expansion.

For these up-to-date facilities, Leopold glazed tile filter bottoms are being used. They were selected because of their past successful performance in the city's Verde plant—also of 30-mgd capacity.

Whether for new construction or plant modernization, an increasing number of municipalities are installing Leopold water purification and filter plant equipment. And for good reasons, too. We'd like to give you details—without obligation.

Leopold

For Top Performance—Use Leopold Bottoms!

F. B. LEOPOLD CO., INC.
ZELIENOPLE, PA.

COMPLETE WATER PURIFICATION AND FILTER PLANT EQUIPMENT • BUTTERFLY VALVES
FILTER OPERATING TABLES • MIXING EQUIPMENT • DRY CHEMICAL FEEDERS
GLAZED TILE FILTER BOTTOMS

Rodney Hunt gates of tough Everdur withstand bleach-plant acid and pulp-mill wastes

Settling tanks of one of the first industrial waste-treatment plants in the paper industry at the Covington, Va., plant of West Virginia Pulp and Paper Co. Everdur was specified for mixing-chamber gates to resist corrosion by bleach-plant acids and pulp-mill wastes.

One of a pair of mixing-chamber gates fabricated of Everdur, each 48" wide by 54" high. The slide is a sheet of Everdur, reinforced by Everdur angles braze-welded in place. Frame and 2" stem also of Everdur.

Resists corrosion. Sewage treatment and waterworks equipment of Everdur* has been in service without replacement for 20 years and longer.

Toughness. Everdur also possesses high strength and resistance to wear and abrasion —so that engineers can use lighter weight wrought material in their designs.

Readily fabricated. Alloys of Everdur are available for hot or cold working, welding, free machining, forging and casting – and can be obtained in plates, sheets, rods, bars, angles, channels, tees, I-beams, wire, tubes, electrical conduit and casting ingots.

Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment" – or for technical help in selecting the correct material for your job. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Limited, New Toronto, Ont.

*Reg. U. S. Pat. Off. 57131

EVERDUR Anaconda's family of Copper-Silicon Alloys

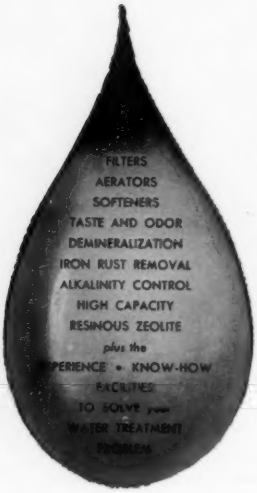
MADE BY THE AMERICAN BRASS COMPANY

STRONG · WORKABLE · WELDABLE · CORROSION-RESISTANT

A GENERAL FILTER

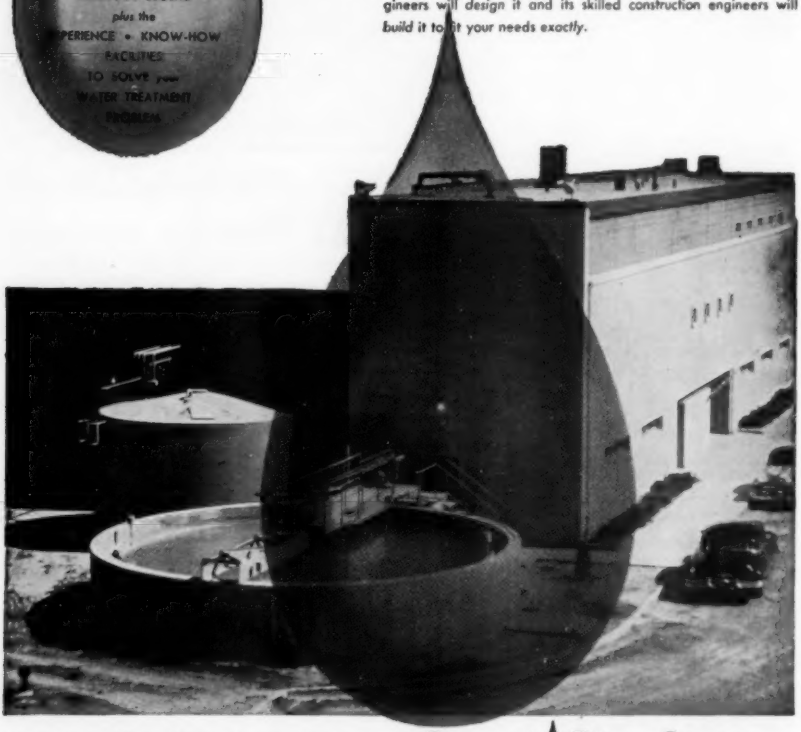
WATER TREATMENT PLANT WILL FIT YOUR NEEDS LIKE A

Prescription!



That's right! General Filter actually *prescribes* a water treatment plant to fit the individual needs and requirements of each industry or municipality . . . designs, engineers and constructs it to assure an adequate supply of *pure* water . . . to provide dependable, economical, trouble-free operation over the years.

That's why more and more industries and municipalities are installing General Filter water treatment plants. They *know* they can depend on General Filter to solve their problem the *right* way. No job is too big or too small. General Filter's field-trained water specialists will *prescribe* a plant . . . its experienced engineers will *design* it and its skilled construction engineers will *build* it to fit your needs *exactly*.



Find out how General Filter solves Water Treatment problems for Industries and Municipalities . . . Find out how General Filter can solve yours.

Write today for complete information . . . no obligation . . .

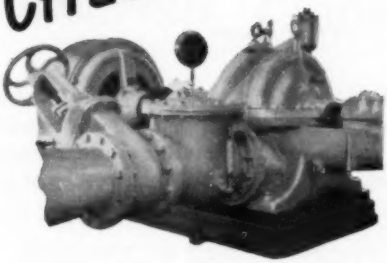
General Filter Company

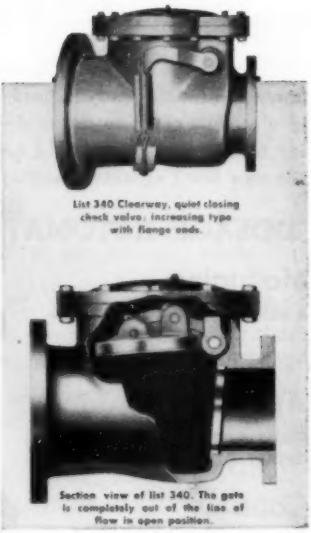
AMES, IOWA

"yours for better water"

CLEARWAY—QUIET CLOSING

CHECK VALVES





List 340 Clearway, quiet closing check valve, increasing type with flange ends.

Section view of list 340. The gate is completely out of the line of flow in open position.

Low cost insurance against severe slam on pump shut down is provided in the Rensselaer clearway, quiet closing, non-slam check valve.

In operation, the gate is normally completely out of the line of flow and head losses are extremely low, even at high velocities. The lever arm and adjustable spring force the gate toward its seat on pump shutdown and the gate seats firmly at the instant of zero velocity, without slamming.

The List 340 Spring Check Valve may be installed in either horizontal or vertical pipe lines and is made in sizes up to 30 inch and pressures of 200 lbs. with flange ends only. Dual levers and springs may be provided for extreme conditions. All parts are readily accessible through the large removable cover.

The increasing type illustrated bolts directly to the pump discharge flange, eliminates increasers and saves valuable space. For locations where slamming is not anticipated, the Rensselaer list 37 without lever and springs is recommended. For higher pressures, the List 39 operates on non-shock cold water, oil or gas up to 400 lbs. W.P. 22

Ask for Bulletin "E"

LUDLOW & Rensselaer

LUDLOW RENSSELAER **VALVES & HYDRANTS**

Since 1861 **THE LUDLOW VALVE MANUFACTURING CO.** Troy, N. Y.

NOW...Dosage Automation

with the

W&T *Quality-Quantity Chlorinator*

Select the residual you want and the new W&T Quality-Quantity Chlorinator will automatically maintain that residual. Immediate sensing of any change in a water's chlorine demand—as well as flow—automatically controls chlorine feed rate to maintain a desired residual. That is Dosage Automation with the new W&T Quality-Quantity V-notch Chlorinator.

DOSAGE AUTOMATION OFFERS THESE FEATURES:

Maintains
a selected residual, free or total, with automatic dosage control.

Anticipates
changes in chlorine demand.

Controls
Chlorine feed up to a full 100 to 1 range at rates to 2000 pounds of chlorine per 24 hours.

Provides
a record of chlorine dosages in p.p.m. and chlorine feed rates in pounds per 24 hours.

Utilizes
the proven W&T V-notch Variable-Orifice for accurate, wide range chlorine feed.

For more information about this new type of chlorination system write for Bulletin S-118.

WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

Journal

AMERICAN WATER WORKS ASSOCIATION

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New Jersey Water Supply Development

Panel Discussion

A panel discussion presented on May 14, 1957, at the Annual Conference, Atlantic City, N.J.

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I AM especially interested in this panel discussion, for, as is probably known, water supply is an issue that happens to have emerged during the last few years as one of the most critical questions facing us in New Jersey. We have become ever more familiar with the problem of keeping pace with the demand for water during a period in which the curve of population growth is moving constantly and rapidly upward, while each day brings forth some new appliance or some new technique of production to increase overall water needs. I, of course, am pleased that you have chosen to arrange a special panel on the situation in New Jersey. Even though at times, in considering the magnitude and complexity of the problem we face, I wonder whether it could be half as serious anywhere else, I am not under the illusion that we have any monopoly on this issue. It seems to me, however, that certain facets of our situation may be unique, and thus I entertain the hope that you will find this discussion fruitful.

You will find, among other things, that the tack we are taking represents somewhat of a departure from tradition. You are men of long and valuable experience in this field, and I suspect that you have developed certain ideas about how a water system should be run. It is the better part of discretion, I think, not to anticipate disagreement. It is possible, however, that some of you may be more or less dubious about our general *modus operandi*. Without belaboring the point, permit me to say that our thinking has been flexible and pragmatic. We want results. Just as we are conscious of the important historic truth that civilizations rise and fall according to their ability to satisfy the need for water, so do we recognize that the vigor of our economy and the general

welfare of several million men and women depend upon the outcome of our efforts to deal with this problem. And after exhaustive studies as well as serious consideration of alternative plans of action, it has become evident to us that the general approach which I propose to discuss today offers the greatest hope for long-term success.

Before turning to these problems, I would like to note a very significant recent development. We have just received the initial report of the New Jersey Water Resources Advisory Committee with recommendations for utilizing the waters of the Raritan River basin. The committee is wholly bipartisan and composed of representatives from industry, labor, and agriculture as well as citizens prominent in the recreation movement. I will not discuss the details of the report because I imagine Mr. Baumer, who follows me on the panel, will go into these. I do wish to observe, however, that the Raritan Basin is the only large surface source of water supply lying entirely within the state where water can be obtained immediately and economically for the northeastern counties and the Raritan Valley.

I am very much impressed with the report. I think the committee has displayed unusual imagination, and, in my judgment, its proposals represent an extremely hopeful approach for exploiting the advantages of this river basin. The report, moreover, will serve as a valuable basis for the kind of public discussion that must precede the adoption of any new water supply program.

New Jersey Water Problem

In one sense, there is no reason why New Jersey should have a water crisis. As far as the potential natural supply is concerned, we have been generously endowed. Our average rainfall is 45 in. a year, hardly the rate of precipitation for a dust bowl. Although our land area is not extensive, and we do not have any long or complex river systems to tap, there are numerous smaller rivers and streams that can be developed. In addition and perhaps even more important, vast quantities of water lie beneath the surface of the state, stored in crevices and pore space of the bedrock, as well as in sand and gravel formations.

It frequently has been noted that the very extent of our water resources accounts, in part, for the present problem. It has been responsible for a certain complacency. Up until the last few years, the voices of the Cassandras who warned of the possibility of water shortages in the absence of an effective long-range program carried a minimum of weight. In point of fact, our most recent major water supply project was completed in the early 1930's.

And so, as it turned out, we awoke in the 1950's to the fact that we had incurred a very serious deficit. It became necessary at times in many communities to ration water and to impose heavy fines on persons who violated bans on its uses for specified purposes. It was clear that the increase in industrial water consumption was outstripping the development of new sources of supply and that our whole program to promote economic growth might be undermined unless we moved quickly to rectify the situation. Along with this, the growing dimensions of the resort tourist trade and community expansion, both along the shore and in the Delaware Valley, have intensified pressure on underground water resources to the degree that certain well fields either have been contaminated by salt water or placed in grave danger of contamination.

Under the circumstances there was no alternative to action—to imaginative, decisive, and immediate action.

As I stressed earlier, we wanted results. And it did not take long to discover that, to get results, the state would have to take the initiative in producing a water supply program. This, no doubt, represented a departure from precedent. It was not a total departure, for since the war the state has operated the old Delaware and Raritan Canal as a source of water for industry and the public, and I understand New Jersey is the only state in the nation now actually engaged in supplying water.* But, generally speaking, as in other states, water supply in New Jersey traditionally has been a municipal function.

If the state has now entered the picture it has done so, in the first place, because of the magnitude and the urgency of the problem as well as the grave consequences that would attend any failure to solve it. State action has been necessary because of the degree of coordination required to convey water over long distances from the sources of supply to areas of need. It has been necessary, because the large amount of capital requisite to acquire reservoir sites and to build additional water supply facilities could not be easily raised by the municipalities concerned, already hard-pressed in meeting the demand for many new services without the benefit of any commensurate increase in revenue. State action has been necessary, finally, because the real answer to our water problem lies in comprehensive, long-range planning, and the state—with its central position and its responsibility for safeguarding the interests of all sections—is best equipped to undertake the planning process.

We have not been free of obstacles in dealing with this issue. I am of the opinion, however, that in the past year or two the public has become increasingly conscious of the problem and increasingly concerned about it, and, on the whole, there has been a corresponding acceleration in our general progress.

State Action

It may be worth while to take a moment to outline specifically some of the things that we have done or are trying to do. The immediate challenge is to relieve the serious shortage in the northeast metropolitan counties. In these counties local water resources have been developed virtually to capacity. Thus, in order to meet future needs, it will be necessary to import water from areas where a surplus either exists or can be developed. This was one of the principal questions facing the State Water Resources Advisory Committee when it began considering recommendations for harnessing the water of the Raritan Basin.

The committee has recommended, as a first step in meeting the requirements of the northeastern counties and the Raritan Valley, that the state construct two moderate-size, on-channel reservoirs in the basin. The necessary capital, the committee proposes, should be obtained through general-obligation bonds, but the water would be sold at a price sufficient to place the projects on a self-liquidating basis.

In the meantime the state has proceeded with the acquisition of a larger, natural reservoir site, known as Round Valley, some distance to the west of New Brunswick, in another step to

* At least one other state—Massachusetts—is in the water supply business, its Massachusetts Metropolitan Water District having been established in 1895 (*1*) to provide water wholesale to communities within 10 miles of Boston.—Ed.

make adequate provision for satisfying the prospective needs of North Jersey. In authorizing acquisition of this property, the legislature stipulated that the reservoir built at Round Valley must be used only for storage of water diverted from the Delaware River. This leads me to the point that in addition to the various measures taken to develop our own water resources, we have joined in efforts to achieve state-federal-local cooperation in carrying out an integrated, multiple-purpose program for development of the Delaware. These efforts have borne fruit to the extent that a comprehensive survey of the basin, under the leadership of the Army Corps of Engineers, is now in progress. Water supply is only one of the considerations involved, but obviously it is one of the paramount considerations for us. We accept as axiomatic our responsibility to develop completely our internal water resources. We know, however, that in time we must be able to draw on the Delaware, and, therefore, are prepared to cooperate to the utmost with other units of government in expediting its development.

A further aspect of the north Jersey situation is the position of the northwestern counties. These counties are not confronted with any water shortages at the moment. Actually they have a surplus. Quite understandably, however, they have been apprehensive lest in the process of tapping water resources in the western part of the state to relieve the shortages of the more populous area to the east, they might be deprived of water that they will need eventually to sustain their own growth. Naturally, we have no intention of permitting anything like this to happen. But, to pinpoint the significance of this apprehension, it seems to me that one of the foremost advantages of a comprehensive, long-term plan to insure an adequate fulture supply of water for all areas is that it helps minimize such fears and the conflict that they generate.

Turning our attention to the southern part of the state, there is, fortunately, no general shortage in this area today, even though, as I have observed, the danger of contamination arising from the intrusion of salt has become very serious at some points. This, however, is a region very definitely on the make. With its location, it has a strong attraction for industry, and this attraction is only increased by the availability of ample space for expansion and the existence of a terrain especially suited to construction of new-model plants and to modern industrial operations. The growth of the region during the postwar years has been substantial. It is virtually certain that future growth will be even more substantial. And if this is true, it goes without saying that the water requirements of south Jersey will multiply on an enormous scale.

The state thus has acquired a 91,000 acre reservation known as the Wharton Tract, which lies in the center of the region and contains water resources of incalculable value. If fully developed, according to one estimate, they could produce a dependable supply of 200–300 mgd.

In laying the groundwork for meeting south Jersey's future needs, we, of course, are now considering long-term plans for developing the Wharton Tract. At the same time the state has initiated a broad survey of underground water resources, and the outcome of this investigation will be important to the area because the findings will serve as a guide to utilizing resources outside the Wharton Tract and should throw more light on the problem of salt water intrusion.

Finally, to be sure, if we succeed in promoting an integrated program for the development of the Delaware Basin, the consequent benefits, such as stream flow regulation and pollution control, will be extremely significant for the growing population of the lower Delaware Valley.

In my remarks today, I have spoken in very broad terms. I hope, nonetheless, that I at least have been successful in giving you a general idea of the nature of one state's water problem and of that state's response to the challenge. I hardly would suggest that our approach is necessarily the best approach for all other states. Every area is confronted with different circumstances, and these circumstances must be taken into account in resolving any question regardless of what it may be. It appears to me beyond dispute, however, that as the latter half of the twentieth century unfolds, water policy will assume an ever more crucial status as a public issue, and, as in the case of New Jersey, every state and every region will be compelled to give it increasing priority.

Reference

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In reviewing the first report of the New Jersey Water Resources Advisory Committee (*1*), to which Governor Robert B. Meyner has paid such generous tribute, I would like to key my discussion to three basic questions: Why does New Jersey need water? What are some of the characteristics of the state's water situation? What is the citizens' committee recommending to meet the state's water needs?

First, New Jersey is a little giant of a state industrially. Two-thirds of the state's economy is sustained by industry. Although it is fourth from the smallest in size, it is seventh from the top industrially. If all the other states in the union were the same size as New Jersey, there would be 370 stars in our national flag.

New Jersey is Number 1 in America in chemical and allied products manufacture. The chemical industry accounts for more than a billion dollars a year in added value to the state's economy.

Besides its top position in chemical production, New Jersey is in the top five states in the production of wearing apparel, instruments, petroleum and coal products, rubber goods, tobacco, and electrical machinery; and in the first ten states in the manufacture of textiles, leather, processed food, and primary metals. Water is absolutely essential to all these manufactures.

Middlesex County, astride the Raritan River, leads New Jersey in chemical production. Within a ten-mile radius of the county seat, New Brunswick, are 80,000 industrial workers—more than are located in either greater Houston or greater Dallas. The area, like many others in New Jersey, needs new water supplies—not just for industry but for residential growth too. The Regional Plan Association, in a recent study, predicted that Middlesex County and the neighboring Somerset and Monmouth counties will double their population by 1975.

New Jersey, the "Garden State," needs water for her farms. The average yield per acre is the highest in America. To keep production high on limited farm lands more irrigation is vital.

Also, our state needs water to develop new recreational areas. This may seem incongruous where we have a beautiful seashore visited by some 4,500,000 people from the other 47 states each year. Many of our more than 5,000,000 inhabitants look to lakes and rivers for their recreation. We need new lakes and ponds and improvement of low stream flows in certain of our rivers.

Increased requirements for water for residential and industrial growth, for irrigation, and for recreation stir up great interest among our citizens. Water is a hot topic, and at times can cause more heated debate than highways, schools, or taxes.

As the governor pointed out, New Jersey has been blessed with an abundant annual rainfall of about 45 in. that falls at almost the same rate each month

Fig. 1. Raritan River Basin Showing Location of Proposed Reservoirs

Curved arrows indicate direction of flow of surface water. Boundary of the Raritan watershed is indicated by dashed lines.

of the year. The problem is to catch the rainfall in reservoirs. Unfortunately, the last major reservoir was constructed in 1930. What increased water supplies are available, other than from that newest reservoir at Wanaque in northern New Jersey, have come from the expanded facilities of a number of the 156 municipal and 93 private water companies in the state and from the sole major regional water association. The plain fact is that we need much more water.

Engineers and geologists tell us that the state actually has more water underground than in all the surface supplies of the state. I will use a layman's prerogative in saying that the southern half of the state is really a floating island. This huge resource is a long distance from the area of greatest need —the northeastern metropolitan area adjoining New York.

With its ground water and rainfall, New Jersey has plenty of water. The problem is to get the people's understanding and their consent to develop our resources.

Two years ago the legislature, acting through a Joint Commission on Water Supply, employed the consulting firm of Tippetts-Abbett-McCarthy-Stratton of New York to make a study of the water resources of the state. The latter's report is extremely well written and comprehensive. As a result of the study a bill was passed and a referendum placed before the voters in 1955 for a $100,000,000 program to build an off-river reservoir along the Raritan River at Chimney Rock in the Watchung Mountains 35 miles southwest of New York City. The necessary bond issue was voted down.

The next development was a legislative bill in mid-1956 for the purchase of another off-river reservoir, known as Round Valley, in the Raritan Basin. The state has now acquired most of the land, but the site remains undeveloped because the authorization to purchase the land restricts the source of water to fill the reservoir to the Delaware River.

Several years before the Round Valley purchase, the state purchased the Wharton Tract—some 100,000 acres of pine barren and swamp a few miles to the northwest of Atlantic City. The daily yield of the Wharton Tract is conservatively estimated at 300 mgd. Thus far there are no customers.

Despite favorable legislative action on the acquisition of potential water sources, the state thus far has no new water supplies beyond the limited amounts developed by existing water companies.

Confronted by this check on the state's growth, a number of prominent citizens decided to join together with the goal of getting new water supplies as quickly as possible. In September 1956, Commissioner Joseph E. McLean, of the Department of Conservation and Economic Development, appointed the New Jersey Water Resources Advisory Committee.

The committee's premise was well expressed in your JOURNAL recently by one of the AWWA members who made the point that if water resources aren't developed, they won't be needed (*2*).

The committee, a state-wide, bipartisan citizens' group, included the heads of the CIO and AFL, the former chairman of the Fish and Game Council, the overseer of the Grange, and several industrialists, editors, and others interested in civic enterprise. The group financed its own work through industrial, commercial, and labor group contributions. They retained the firm of Whitman, Requardt & Associates of Baltimore to make an engineering sur-

vey of the problem, using, insofar as possible, the studies and data available.

Guiding Principles

To guide the engineers and itself, the committee adopted the following statement of guiding principles:

1. The State Water Resources Advisory Committee is statewide in scope. It will be necessary to plan for water needs years ahead with a program of development by stages. The first step might be to provide for the next ten years, and each of the subsequent stages to provide for equally long periods. Cost estimates will be needed for each stage. Recommended projects should fit into existing and planned water supply programs.

2. We would want to point to the immediate acquisition of the sites necessary to the complete program to avoid higher costs later and to minimize inconvenience to the public. Cost estimates of such acquisitions will be needed.

3. We regard it important to provide complete, satisfactory assurance to upriver counties that there would be no lowering of their optimum lake and stream levels and that such counties would always have sufficient water for their own needs and growth.

4. Raritan water supplies are to be developed for use in the basin, for northeast New Jersey, and other parts of the state. The water may be used for potable needs, industrial purposes, irrigation, recreation, and stream regulation.

5. The legislature has stipulated that the water for the Round Valley Reservoir must come from the Delaware River. However, we should be prepared to recommend Raritan Valley water sources to the legislature if it should later find that Delaware River supplies are not available, not available soon enough, or not available in sufficient quantity to make optimum use of the Round Valley Reservoir.

6. We would give consideration to the relative merits of supplying raw water or filtered water to meet the different needs of potential customers. Similarly, we would give consideration to the question of whether water should be delivered or provided on a come-and-get-it-basis. Accordingly, any plan should be designed to enhance rather than jeopardize the activities and programs of existing water companies and commissions.

7. Use of the Raritan watershed rivers and streams to carry the water supply to the points of use or nearby is a desirable goal. The anti-pollution programs now underway in the Raritan River Valley materially increase the feasibility of such a plan.

8. We should strive to have a minimum daily flow of 130 mil gal in the Raritan at Bound Brook below the Elizabethtown Water Company intake. Consideration should be given whether this minimum daily flow might be reached in stages. The plan should provide an initial basic minimum flow of at least 100 mgd.

9. In addition to that initial basic minimum river flow of 100 mgd, we would strive for an additional 100 mgd which would be available for sale to water supply companies, industries and municipalities; an initial minimum flow of 200 mgd in the Raritan at Bound Brook below the Elizabethtown Water Company intake.

10. We must give consideration to the use of both gravity flow and pumping wherever each is most feasible. The questions of supply, dislocation of people and other conditions are all-important in this connection.

11. We want to achieve the maximum of protection against soil erosion. In these and in other respects we want to give consideration to the federal aid which may be available for such purposes.

12. While primary consideration must be given to the foregoing factors, we want to take advantage of practical opportunities for considered land improvements and recreation facilities.

*13. Water supplies to meet the anticipated needs may be made available from either on-river or off-river reservoirs, or from any combination of reservoirs.

*14. Any water supply project will be self-liquidating.

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* Approved at February 14, 1957, meeting of the Water Resources Advisory Committee.

I particularly call your attention to Principle No. 6, because it is a businesslike approach. To the engineers the committee said: "We are not sold either on natural water or filtered water; you tell us what are the advantages and disadvantages of each and the comparative costs." In No. 7 the Committee wanted to know if the river could be used as a conduit and water sold at the dams and at various points downriver.

Principle No. 3 has in the past been a political issue. On previous legislative proposals for water development it has been alleged that the reservoirs will drain certain lakes. From an engineer's standpoint it was not always a logical statement, but from a citizen's point of view, a difficult charge to counter.

As regards Principle No. 14, the committee wanted to be sure that any project would be paid for by the water users and not by taxpayers elsewhere who would receive no direct benefit. You may have heard that we have a Mason-Dixon line in New Jersey on occasion. What's good for northern New Jersey may be voted only if southern New Jersey will support it and vice versa. The financial recommendation is for a general-obligation bond issue backed by the faith and credit of the state. Revenues from the sale of water would be designated for bond interest and retirement of principal, just as highway tolls have been designated in the state.

Committee Recommendations

The Raritan Basin (Fig. 1) has the greatest quick potential intrastate in New Jersey for the development of water supplies near the area of greatest need. It therefore became the subject for first consideration.

As a result of the engineering studies and committee deliberations, as well as discussions with legislative and administration leaders, the advisory committee, in its first report on April 25, 1957 (*1*), recommended the acquisition and building of two on-river reservoirs at the far reaches of the Raritan Basin at a cost of $14,000,000: the first at Spruce Run, off the south branch of the Raritan; and the second at Stony Brook, a tributary of the Millstone River. These would be balancing reservoirs supplying water and improving the low river flow between the dams and the confluence of the Raritan and Millstone Rivers (Table 1). The river would be used as the conduit from the dams and water sold at any point down the river to the confluence.

TABLE 1

Effect of On-River Reservoirs on Flow at the Confluence of the Raritan and Millstone Rivers

Reservoirs	Capacity *bil gal*	Sustained Minimum Flow *mgd*	Water For Use *mgd*
None (present)	—	45	20
Spruce Run	10	90	60
Spruce Run & Stony Brook	20	100	100
Spruce Run, Stony Brook & others	50	120	200

The plan is to sell raw water at approximately $25 per million gallons. Riparian owners and purchasers of water could draw water from the stream bed. Transmission and filtration would be their responsibility. The project would be materially helped by the interlocking transmission system already in existence north of the Raritan River.

The state under this recommendation would be in the wholesale water

business, selling natural water to municipal and private water companies, to industries and farmers. While this recommendation for state administration and operation of a water system may seem somewhat radical, it should be noted that currently New Jersey operates the Delaware and Raritan Canal as a water resource. The state department of Conservation and Economic Development now operating the canal was recommended as the preferable manager of the proposed on-river project.

The Spruce Run Reservoir would have a 10-bil gal capacity, with 41 sq miles of drainage area and 1,240 acres of reservoir behind a dam 80 ft high.

The Spruce Run Reservoir will develop 85 mgd in the Raritan River running to Bound Brook, 45 mgd to improve the low-flow stream regulation, and 40 mgd for sale in the bed of the stream.

Stony Brook Reservoir, west of Princeton, would have a like capacity of 10 bil gal. There would be 38 sq miles of drainage area behind the 70-ft dam and the 1,520-acre reservoir.

The latter would provide another 10 mgd of stream regulation flow en route to and at Bound Brook so that the Raritan, which runs at 45 mgd at times of extremely low flow, would be considerably improved. These two dams would more than double the guaranteed, sustained low flow. Adding Stony Brook Reservoir's 40 mgd, there would be a total of 80 mgd for sale each day. This relationship is shown in Fig. 2.

The project has the advantage of simplicity and relatively low cost. The dams can be built and in operation within 3 years of authorization The

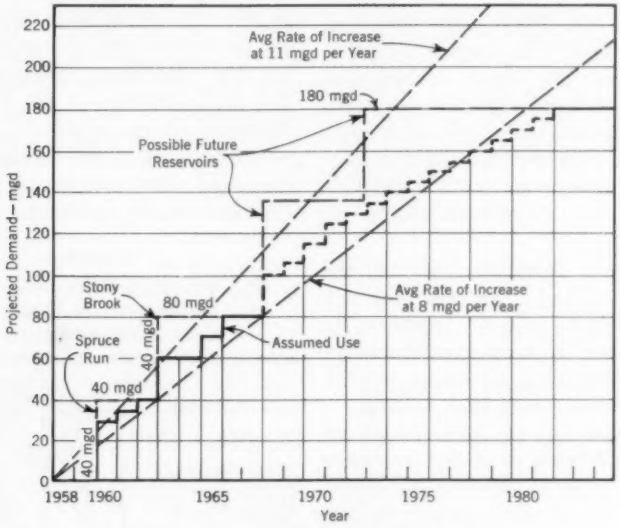

Fig. 2. Projected Water Demand

Shown above is the relationship between the proposed reservoir yield for use and the projected demand.

reservoirs would displace only a limited number of families, a very serious problem in New Jersey. Chimney Rock Reservoir would have displaced 420 families, and thus became a heated campaign issue. The Spruce Run site has 60–70 families and Stony Brook 30–40. The self-liquidating basis for the project is also a big advantage.

Still another plus factor is that the reservoirs would provide more recreational areas. Such use of the on-river reservoir water is feasible because it will be filtered before being used for potable needs, and it will have traveled some distance downstream before being picked up.

More water supply would mean more jobs for New Jersey citizens. New industries would come into the "Garden State" in greater number and resident industries would be more inclined to expand in the state. Firms that need water want it readily available and at a competitive rate. These are two of the greatest advantages of the on-river reservoir project on the Raritan.

In southern New Jersey, where there is an abundance of underground water, there is a booming industrial development. Assured growth in northern New Jersey rests with the advisory committee's first recommendations for obtaining 80 mgd from the Raritan.

Development of the Raritan Basin water supply potential fits into the overall program for the development of water supplies in the state. The Water Resources Advisory Committee has scheduled a follow-up study on methods for developing the further potential of the Raritan by at least an additional 100 mgd.

Other engineering studies are being made by the committee's ground water consultants—Leggette, Brashears & Graham of New York.

A still later development of water supplies for New Jersey inevitably leads to the Delaware Basin.

The work in progress and under contemplation will develop water supplies needed up to the year 2000.

The citizens' committee's first report will, it is hoped, end in legislative action and perhaps another referendum. I am sure that the members of your Association will watch with interest the future course of the committee's recommendations for meeting New Jersey's immediate water needs. The guiding principles shown earlier will be put to the test of voter reaction, as will the the basic question of whether the state should go further into the business of selling water wholesale.

References

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Growth in population and industry, coupled with the demand of both for more water as the recognition of its advantageous use has progressed, has resulted in water deficiencies in many parts of the world. From a standpoint of volume alone, the shortages in the United States have probably surpassed those of any other nation.

Although the fundamental need for more water in New Jersey is not materially different from that of other states, the reasons and degree of additional requirements are unique. It is the purpose of this discussion to point out some of these features in a manner that has not heretofore been done largely

because most individuals capable of so doing have felt a restrictive hand on their shoulder while speaking.

Physical Limitations

The land area of New Jersey is approximately 8,000 sq miles. In a very dry year the rainfall in the state approximates 36 in. With about 50 per cent of this collected as runoff in streams, and somewhat less than 50 per cent available from areas in which wells are useful, because of the impossibility of diverting all ground water, it is reasonable to estimate that not more than 10 in. of water is actually susceptible of use. Natural stream flow requirements, including navigation, recreation, dilution of sewage treatment plant effluents, power plant needs, irrigation, transpiration by vegetation, and many other demands, are such that this last figure may easily be cut in half.

It is important to point out that a large portion of the area of New Jersey is already used as a potable watershed. The downstream users have in many instances been very jealous of the rights which they have been enjoying for 50 years or more. Great difficulty is encountered in any attempt to establish further diversions on these watersheds that are so dedicated. Hence the normal physical limitations may, and often are, superseded by other considerations.

Simple arithmetic then shows that the total water assets of New Jersey are less than 2 bgd. This assumes development of water on every square mile of area in the entire state—a physical impossibility. Actually, most engineers will agree that 1 bgd is a much more realistic limit that may be established as a probable goal.

At present, water requirements in the heavily industrialized northeastern part of New Jersey are well in excess of 400 mgd for potable uses alone. Total potable uses are approximately 600 mgd for the entire state. Industrial uses have not been accurately determined but they are substantial. It becomes essential, therefore, to apply unbiased planning to make best use of the indicated firm margin of 400 mgd that exists between supply and demand for potable uses alone.

Competition

It is doubtful that any other area in the United States has suffered so much from competition between various agencies for customers and for supremacy. In some respects this has been going on in New Jersey for more than a century and it is just as prevalent now as ever. Perhaps the forerunner in bringing this matter to a head was the effort to establish a state water agency in the 1880's. This failed, but another state water commission with broad powers was legislated into existence in 1907. It functioned importantly until its powers to issue bonds were refused and the Act of 1916 inaugurated the North Jersey District Water Supply Commission to function in constructing the Wanaque supply for a group of municipalities. A south Jersey district was also authorized, but has never been activated.

During the 1920's a further struggle for the right to develop another large water project broke out anew with the state and the North Jersey District commission competing. The depression halted hostilities temporarily, and World War II kept them somewhat inactive. Ever since the war there has been a resumption of efforts, and they still continue.

In the background there have been the municipally and privately owned water agencies that have, in many instances, had their own ambitions both

as to water rights and customers. With pipelines that cross and recross, it may be easily understood that such a situation could develop.

Within the last 30 years there have been very few legislative sessions that have not seen the introduction of a group of water bills, each sponsored by some individual or agency that has a particular ambition to achieve, usually at the expense of someone else. Some of these bills have had good intentions, but the number that could be really beneficial could be counted on the fingers of one hand. Furthermore, most of them can be classed either as selfish or ripper legislation.

Fortunately the great majority of these bills fell by the wayside. The two bills passed in the 1940's, that dedicated the Delaware and Raritan Canal, first for industrial water use and later for additional potable use, are examples of water legislation by which New Jersey has benefited. The 1956 bill authorizing the purchase of land in Round Valley, while having some good features, is an example of how political expediencies have set aside good engineering judgment.

Suffice it to say that in general the water systems in New Jersey have struggled along, possibly hampered by legislation rather than helped by it.

Water Rights

In the latter part of the nineteenth century, private capital was attracted by the growing demand for upland water supplies created by the hue and cry for uncontaminated sources. The lower Passaic River, from which the bulk of water used in Passaic, Essex, and Hudson counties was then obtained, had become grossly polluted. Typhoid fever was on the rampage, and action was imperative.

Purchasers of land and water rights along upper parts of the Passaic River watershed were widespread under the guidance of privately owned water companies. In 1889, when Newark signed up with these interests for the Pequannock supply, a large portion of that watershed had already been purchased. The city continued for many years to acquire additional property and it now owns roughly two-thirds of the entire 63 sq miles of watershed.

Jersey City, after acquiring the Rockaway supply, also purchased substantial areas on the watershed, but with the purpose mainly of having available the necessary sites for future additional reservoirs.

While lands so held are taxed by the local municipalities, they are subject only to a nominal land value assessment, because many of the original buildings have been removed. This has given rise to a great hue and cry by local politicians (principally in Morris County, which embodies a substantial part of such watershed lands) that the lakelands are being subjected to tremendous hardships. Such claims are usually fantastically erroneous.

An example exists in the case of Budd Lake, the largest natural lake in New Jersey. In order to control the level within a very small variation, a small concrete dam, perhaps 20–30 ft wide and a few inches high, was erected across the outlet brook. Slots exist in the dam to permit use of flash boards. Under no circumstances is it possible to create a variation in the lake level of more than a few inches. Yet in trying to combat the Round Valley plan, the Morris County delegates to the legislature stated positively that the proposal to send water into the Round Valley Reservoir (which water would come from the south branch of the Raritan River with Budd Lake as the

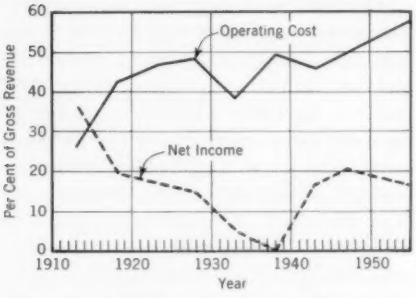

Fig. 3. Income and Costs of Municipal Water Utilities

Figures are based on percentages of gross revenue of the five largest municipally owned water utilities in northeastern New Jersey.

headwaters) envisioned the draining and ruination of Budd Lake. It is inconceivable that the men who made such statements could actually believe such sheer nonsense. It might be interesting to know how they would attempt to prove such utterances under oath.

One further point of disparity exists between what the powers that be in Morris County say and what they do. The Picatinny Arsenal and the Lake Denmark area, on which are manufactured and stored munitions for the Army and Navy respectively, have for years been expanding their holdings and taking them out of the local tax structure. Nevertheless, no word of protest is heard from those people who scream every time a dam or reservoir is mentioned.

This cause of the stagnation of water planning defies any logic. Its intentions may well be questioned.

Lack of Funds

Money, conspicuous by its absence, is the root of much of the evil that exists in the water dilemmas of New Jersey. Fundamentally, the cause is antiquated rate schedules that are as out of date and unrealistic as a 1920 automobile. This may be demonstrated graphically by the curves in Fig. 3 and 4, which clearly establish the sad financial picture of water works operations in northeastern New Jersey over the last 42 years. It is most probable that the same condition is generally true throughout the state. Certainly it is not any surprise to water works men in the rest of the nation.

The only reason that water systems have managed to stay in business at all within the last two decades is because of the tremendous increase in their output. But they have been living in a fool's paradise. The day of reckoning has already passed.

The municipalities have suffered from increased operating costs, and still have to meet huge bond retirements out of a somewhat misleading net income. When they have to finance new capital additions, a woeful picture will be presented.

Private companies have managed to keep operating costs at a somewhat reasonable level, but increased taxes have had a most significant effect on their net income.

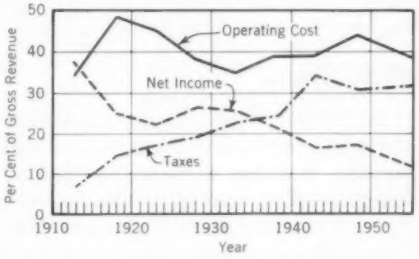

Fig. 4. Income and Costs of Private Water Companies

Figures are based on percentages on gross revenues of the five largest private water companies in northeastern New Jersey.

What are they doing about it? The municipalities quoted have finally awakened to reality, after a great deal too much procrastination, and are beginning to adopt more realistic rate schedules. Some of these have been in effect a few years and have been beneficial in permitting adequate expansion plans. The largest city, Newark, has just recently received a comprehensive report on a very substantial recommended rate increase. Other municipalities are still caught in the vicious spiral created by inflation on one hand and the reticence of elected officials on the other hand to invite criticism of the voting public by increasing water rates.

The private water companies have struggled with rate increase schedules for many years and, to their credit, have managed to obtain some reasonable adjustments, in spite of the necessity for establishing a rate base on book costs of their properties. It seems strange that municipalities, not being subject to the same regulation restrictions as companies, have failed until recently to take advantage of their freedom of action.

The greatest deterrent to the carrying out of the Round Valley project, as presented by the North Jersey District Water Supply Commission in 1954 to a group of eight applying municipalities, was the lack of sound revenue-producing rate schedules that would permit participation in such a venture.

Summing up this section on lack of funds, the word "penurious" seems most appropriate. Instead of doing, as some cities have done, a selling job to industries on the basis that their water rates are lower, cities should be stressing availability, with rates as a very minor secondary consideration. The water companies have adopted this latter policy, at least in part, and it has been beneficial to them. As a result they are much further ahead on their badly needed expansion programs than are the cities.

Water Waste

Every water system suffers at one time or another, and quite often continuously, from an unnecessary waste of water. In many instances the waste is largely unavoidable. Where systems are fully metered, frequently the only way to reduce waste is to inaugurate an intensive drive such as the one invoked in the 1949–50 drought. This type of campaign is not an unmixed blessing. In one municipality that prided itself on the effectiveness of its campaign, it became necessary to establish a temporary surcharge of 33⅓ per cent on all water bills, because the billings showed clearly that the revenue to be received would not keep the water department solvent. On the other hand, another municipality that stressed leaky services and fixtures was so successful that the meters actually recorded a much larger per cent of water produced, and the net result was a fairly well balanced budget. Water companies usually suffer adversely from any concentrated drive for curtailment.

While the great bulk of the services in the densely populated northeastern part of the state are metered, there are some large cities in other parts of the state that have not metered residences. Also, many of the shore resorts have preferred to omit meters.

One of the large cities in the state has declined to install meters because of an anticipated decrease in revenues, but, on the other hand, has had to spend large sums for facilities to meet increased demands, part of which are occasioned by lack of meters.

The state authorities having jurisdiction over grants of water are prone to insist on 100 per cent metering for all new diversion grants. Is it fair, however, to force small communities, particularly resort areas, to install meters and not to require similar activity in large cities?

Developments

The Hackensack River watershed, now being further developed by the Hackensack Water Company may be subject to some additional increases in the future, but these will merely meet the needs of the area now served.

The Passaic River watershed is the largest in northeastern New Jersey and is the one most intensely developed. Newark and the Commonwealth Water Company are actively engaged in expanding their facilities on the watershed. Jersey City has applied for additional diversion rights and the Passaic Valley Water Commission has plans for taking more water from the stream. These will result in as nearly a complete usage of the watershed as is reasonable or advisable.

It is to the Raritan River basin that attention has been directed for the last 40 years as the greatest potential source for expansion to meet the needs of northeastern New Jersey, because its present development, while increasing all the time, is still well below that which is possible without injury to riparian owners.

The state of New Jersey has purchased the extensive Wharton tract in south Jersey on the Mullica River watershed. It is hoped that when the need for water from that source is felt, enabling legislation will be forthcoming to expedite its use. Actually the activation of a south Jersey district water supply commission, which can be instituted under existing statutes, could serve the needs if the municipalities interested would show sufficient initiative to warrant such action. Present indications do not lend hope to such a possibility.

The author has for nearly 40 years advocated the development of Round Valley and has had hopes of seeing this mature in accordance with a plan submitted in a report by the North Jersey District Water Supply Commission in 1954. The bait of state funds, however, was too strong to be denied, with the result that other engineers were engaged by the state to make a report in 1955. As a result, the already long discarded Chimney Rock plan was exhumed, given a new coat of paint, and foisted on the electorate for consideration in November 1955. The citizens agreed with the majority of the water works men, and the plan was buried with neatness and dispatch.

Unfortunately, the confusion resulting from this abortive effort permitted the so-called lakeland interests to consolidate to prevent the use of any water from the Raritan River basin in the enactment of 1956, giving the state the power to purchase Round Valley as a reservoir site. The clause providing for the use of only Delaware River water is a 15–20-million dollar road block thrust in the path of a public that is bewildered by the cross currents of various reports.

Needs

For many years the large industries in the Raritan River Valley have felt the growing need of water. It is only natural, therefore, that they should foster a plan to assure an adequate flow of water in the lower valley. The advance information on this plan indicates that two reservoirs are advocated;

presumably, they will make available a large quantity of water.

While it may be true that large volumes of water may flow down the Raritan River from the storage basins mentioned in the preceding paragraph, there is one feature that many engineers, and almost all laymen, fail to recognize. This is the matter of temperature of the water.

From long experience the author has learned that potable water, in order to be palatable in the summer, should be as cool as it can be reasonably made. Obviously, because there is no economical method for cooling water in large volumes artificially, the result must be that provided by nature. This requires long storage in a deep reservoir.

There are cases in New Jersey, well authenticated, where consumers, given the choice, have expressed a preference for cooler supplies. From a potable standpoint there may be no choice between some of the various sources, but from a palatable standpoint the cool supply will get the preference almost without fail. There is absolutely no substitute for low temperature in a water supply.

New York City rejected the Hudson River source, very largely for reasons of palatability. Can people in New Jersey be less discriminating?

Future Program

A suggested program for the future may be summarized briefly as follows:

1. Revise the statute authorizing purchase of Round Valley so as to permit diversion from the Raritan River basin.

2. Plan construction of the Round Valley Reservoir under whatever method of financing may be feasible.

3. Permit operation of Round Valley by the North Jersey District Water Supply Commission with amendments to the present district act suitable to permit a flexibility of operation.

4. Construct one dam in the Raritan River basin for the express purpose of augmenting the downstream flow in dry weather.

5. Defer construction of any other future low dams in the Raritan River basin until the tremendous compensation water storage of Round Valley is fully utilized. (This will also involve some questions on cost, for which figures are not presently available).

Finally, an old saying can be applied: "Don't wait for the cow to back up to be milked. Go after the cow."

Review of Oregon Water Law

Fred Merryfield

A paper presented on May 14, 1957, at the Annual Conference, Atlantic City, N.J., by Fred Merryfield, Prof. of San. Eng., Oregon State College, Corvallis, Ore.

PERHAPS no region of similar size in the United States has so wide a variety of climate as does Oregon. The state is approximately 95,000 sq miles in size, is divided equally north and south by the 44th parallel on the west coast of the United States, and is bounded on the north by Washington and on the south by California.

Climatic Features

The winds from the Pacific Ocean move from west to east. The first interception of this humid air is the coast range of mountains, which parallels the coastline a short distance from the ocean. The rainfall on the coast is about 70 in. per year, and on the tops of some of these mountains, annual rainfall of 115 in. has been recorded. The Willamette Valley is about 200 miles north and south and about 60–70 miles east and west. The annual rainfall there decreases very rapidly to about 38–40 in. This annual precipitation is comparable to that of Chicago or New York. The Cascade Mountains, which are on the eastern border of this valley, receive much of the remainder of the moisture, with annual precipitation as high as 70 in. This range has several snow-clad peaks of 10,000-ft elevation.

A great portion of central Oregon, comprising over two-thirds of the area of the state, is a high plateau ranging from 2,000 to 4,000 ft in elevation. There the rainfall diminishes extraordinarily rapidly to as low as 10 in. One might say that a third of the state of Oregon has rainfall of between 10 and 15 in. per year. A further wringing out of these clouds from the Pacific takes place on the border between Oregon and Idaho, in the Blue Mountains and the Wallowas, where precipitation averages 25–30 in.

In western Oregon, the temperature ranges from 80°F in summer to occasional lows of 25°F in winter. The general winter temperatures are in the low forties. In central and eastern Oregon, the summer temperatures are in the nineties, while the winter temperatures drop below freezing, occasionally for weeks at a time.

The summer humidities often fall below 30 per cent throughout the state, causing shutdown of all logging operations. The summer rainfall is slight from late June to mid-September.

Although the amount of annual precipitation varies greatly throughout the state, there is an amazing uniformity during the period of peak water use, from May to October, which is the irrigation season. When the peak needs arise for recreational uses, municipal requirements are also at their highest point. Industrial requirements, par-

ticularly in the processing of agricultural crops, are likewise at their peak.

During this period, stream flows are at their lowest point (except for the Columbia River), while average precipitation during the summer months amounts to approximately 2–3 in., both in the arid area of eastern Oregon, with its average rainfall of 10 in. per year, and on the narrow coastal plateau, where the rainfall is about 70 in. per year.

Runoff

The runoff of the western rivers, fed by rain and snow melt, is at maximum in the winter months. The Willamette River at Albany, with 5,000 sq miles of drainage area, produces an annual mean flow of 14,000 cfs. The unregulated low flow has been recorded below 2,000 cfs, and the maximum flood is about 250,000 cfs.

The mean flow of the Colorado at Lee's Ferry, Ariz., has approximately the same mean flow as the Willamette at Albany; the drainage area at Lee's Ferry, however, is 107,000 sq miles. The Deschutes, another northward flowing river just east of the Cascade Mountains, has a maximum flow of 43,000 cfs, a mean of 5,800 cfs, and a low of 3,400 cfs, from 10,500 sq miles of drainage area. The John Day, about 60 miles east of and parallel to the Deschutes, has a maximum flow of 39,000 cfs, a mean of 2,000 cfs and a low of 4 cfs from 7,600 sq miles of drainage area. The giant Columbia produces a mean flow of 195,000 cfs from 237,000 sq miles of drainage above the dam at The Dalles, Ore. The maximum flow is 1,200,000 cfs, and the minimum is 35,000 cfs. Several rivers drop 4,000–5,000 ft per 100 miles. The coastal rivers are large in the winter, but diminish to streams of 30–50 cfs in the late summer.

Industry and Agriculture

The range of rainfall in Oregon varies from lows comparable to some recorded in Arizona and California to highs as great as any recorded in the United States. This physical factor is only one of the many water problems in Oregon. Because of the absence of oil, coal, and—until very recently—natural gas, the people of Oregon and the Pacific Northwest have been dependent upon hydroelectric power to meet their energy requirements. Production of hydroelectric power involves dams to utilize the head to furnish the necessary kilowatts.

The Pacific Northwest is also the home of many species of anadromous fish. Such fish begin and end their life cycle in the fresh-water streams which are the headwaters of the major rivers. The young migrate to the sea, returning to the headwaters to spawn a new generation and then die. One of the basic problems in this area is whether to use the rivers for production of hydroelectric power or as a passageway or highway for fish.

The Columbia River has long been famous for the commercial salmon fishery industry. Forty years ago draft horses were used at the mouth of the Columbia to pull in nets loaded with salmon. The Umpqua, Rogue, and McKenzie rivers are known to salmon and trout fishermen the world over.

Log rafts have and are being towed on the western Oregon rivers to the sawmill and the pulp mill. Ocean-going log rafts 1,000 ft or more in length were in use for 40 years, traveling from the Columbia to San Francisco and Los Angeles.

Out of the 61,000,000 acres of land in Oregon, 29,000,000 are in forest. Of this forest acreage, more than 26,000,000 acres have commercial timber of a stand of 450 billion feet of commercial saw logs. The federal and state governments own 55 per cent of the forests in western Oregon and 71 per cent in eastern Oregon. Municipalities and state agencies own 4 per cent of the commercial forest. An appreciation of the forests of Oregon can be gained by visualizing a forested strip of land 15 miles wide reaching from Astoria, Ore., to New York City. The state produces 25 per cent of all the soft wood of the United States, 46 per cent of all the plywood, and 25 per cent of all the hardboard. Sixty cents of each industrial dollar is produced by the forest and allied industries.

More than 1,000,000 acres of land have been under irrigation for two or more generations. Few of these projects have produced surplus crops. More than 150,000 acres have been irrigated supplementally in the Willamette Valley, and more than 500,000 acres are still available for this type of irrigation.

In the last 70 years and particularly the last 40, hydroelectric power plants were built to serve the energy needs of the growing, vigorous population. In more recent years, the federal government has built on the Columbia and the Willamette numerous multipurpose dams. Most of them on the Willamette store winter flows, control floods, and release water in the summer season. Some of them have provided excellent recreational areas.

Within the last 15 years, municipal sewage treatment plants have been built so that more than 90 per cent of the urban population has treatment facilities. The pulp and paper industry stores its strong wastes during the low-flow periods and discharges during the above critical flows. Heavy pollution in a section of the Willamette River near Portland has been partially removed, with the consequent improvement for the return of the fall run of salmon from the sea. Some improvements are being made with disposal of other industrial wastes.

The federal government owns more than 50 per cent of the land of the state of Oregon. Some of this is forest, and a large part is arid rangeland.

Water Appropriation

A peculiar characteristic of Oregon, as well as of the other seventeen western states, is the matter of appropriation of water. In the early days, the miners and pioneers who crossed the plains in search of both metals and irrigable and productive land found that it was not necessarily true that the water and the metals or the best lands were contiguous. It became necessary to divert the water from the streams to the point of use. From this concept was born the doctrine of appropriation now in effect in the western states.

This doctrine has been recognized in Oregon for over 100 years, although the first appropriation laws were not enacted until 1909, when the surface water code was established. (The first proved water right in Oregon was taken up in 1852.) This code, in effect, established a water policy for Oregon effective and workable as of the time of its enactment. Briefly stated, the doctrine held that the water belonged to the state, and citizens were allowed to use the water without waste as long as the use was beneficial. It further provided that the use was

predicated upon "the first in time, the first in right." This concept worked admirably when the number of uses was limited and the population served was small.

As society became more complex and population grew, however, there came the request for the enactment of a series of laws establishing single-purpose or single-interest agencies—the Hydroelectric Commission, Fish Commission, Game Commission, Reclamation Commission, State Sanitary Authority, and others. One disadvantage to the creation of these various agencies was the fact that every time the legislature created a new agency in a specialized field, it, in effect, created a water policy that pertained to that particular interest or agency. The result was that these agencies, as those on the national scene, while good individually, did by law develop areas of conflict between themselves and the people enjoying the benefits of the agencies' works.

In 1953, the state legislature formed an interim committee for the purpose of evolving a coordinated system for water resource development and reporting its findings back to the legislature at the 1955 session. This interim committee made a very serious study, holding hearings throughout the state, and developed an outstanding report as the result of its findings. The hearings indicated the need, in the eyes of the people, for, first, a state water policy, and second, one agency to administer this policy. The committee recommended that this agency should have authority to resolve conflicts arising over the use of water under the standards set forth in the recommended state policy and that it should foster project development insofar as practicable in conformance with the state water policy. These findings were presented to the 1955 session of the state legislature, which enacted them into law, creating and establishing the State Water Resources Board. In enacting this legislation, the legislature abolished four agencies.

Provisions of Law

Following the normal declaration of such an act, the law establishing the board goes on to state that proper utilization and control of the water resources of the state can be achieved only through a coordinated, integrated state water resources policy, through plans and programs for the development of such resources, and through other activities designed to encourage, promote, and secure their maximum beneficial use and control—all carried out by a single state agency, the State Water Resources Board.

This board consists of seven members, each appointed by the governor for a 4-year term, subject to approval by two-thirds of the senate. Members receive no compensation. The board employs a secretary and, at its discretion, may employ other personnel, including engineering, legal, and technical people, to aid in carrying out its functions.

Since 1909 the state of Oregon has controlled the use of its surface waters by means of the water permit and certificate. Procedure includes the initial issuance of a water permit, a proving up period, and the final issuance of a certificate. The issuance of certificates is the responsibility of the state engineer, who keeps complete and adequate records of each permit and right given. The state of Oregon works under the doctrine of beneficial use, which is the

nominal doctrine of many of the western states.

The board cannot change the existing rights or the established duties of water and relative priorities concerning the use of water. All the laws governing them are to be protected and preserved subject to the principle that all of the water within the state belongs to the public for the use by the people for beneficial purposes without waste.

The board was to proceed as rapidly as possible to study all water resources of the state with means and methods of conserving and augmenting these resources, determine contemplated needs and uses for water for every purpose, all of which are declared to be beneficial. After such studies have been made and opportunity given to all state agencies and others to be heard, the board is then progressively to formulate a graded, coordinated program for the use and control of such water.

Multipurpose impoundment structures are to be preferred over single-purpose structures, and upstream impoundments over downstream. Fishery and recreational aspects of the use of water are considered an economic and important asset. Subject at all times to existing rights and priorities, the board may classify and reclassify lakes, streams, underground reservoirs, or other sources of water supply for the best future use, in order to develop an integrated and balanced plan.

The board must diligently enforce existing laws concerning cancellation, release, and discharge of excessive unused claims of water, and may, subject to existing rights, priorities, and preferential uses, prescribe preferences for future use of particular streams or lakes. The board is commanded to deliver a copy of each water resource statement to the state agencies or public corporation which may be concerned by the announcements. As in laws of this character, certain legal procedures are described which the board must follow, concerning hearings, agreements, rules or regulations, and protests. There is a section on violation by any state agency or public corporation receiving a copy of the state water resources statement. The section gives the board responsibility for applying to the circuit court of the county in which such a violation is alleged to exist for restraint by appropriate process of the commission.

The board may also determine, when necessary to insure compliance with the state water policy in the public interests and to conserve waters of the state for the maximum beneficial use, that certain natural flows or impoundments may be withdrawn from appropriations for all or any users. The board, on behalf of the state, may issue this withdrawal order. This, of course, is not done without a public hearing on the necessity for such withdrawal, and the order must specify particularly the water drawn from appropriation, as well as purpose. The board itself may modify or revoke its order. The board also represents the state in the formulation of informal or formal compacts or agreements by legislative assembly, and assists voluntary committees, state agencies, or the federal government in carrying out such programs as are deemed necessary. The board also may conduct, alone or in conjunction with others, surveys or studies relating to the development of the water resources of the state. In addition, the board may accept and expend money from public or private sources, including the federal government, for the

purpose of encouraging, promoting, and securing the maximum beneficial use.

The beneficial uses as stated in the legislative policy of the act are: domestic, municipal, irrigation, power development, industrial, mining, recreation, wildlife, fishlife, pollution abatement, and all other related subjects including drainage and reclamation.

Resources Board Activities

The board's activity since its inception in August, 1955, has consisted of education of the board and its staff, of the various agencies with which it works, and of the public with whom it deals.

This giant assignment was to be operated under a rather modest budget, and it was the belief of the members that the board would use every facility within its power, from all public and private bodies, in order to arrive at some bases or criteria for water policy statements.

It was realized at the outset that this was a continuing job in a pioneer field. It was, therefore, proposed to obtain as much as possible of the basic data concerning the water permits and certificates which had been issued to date. It was decided that it would be impossible to study the state as a whole, due to the enormous differences in topography and runoff characteristics of the drainage areas; therefore, the state was subdivided into several drainage basins.

It was also found that the private and voluntary associations were sources of much information and background for the board to use. Previously, the Willamette River Basin Commission, which the board had replaced, had been very active in the development of flood control on the Willamette River. This commission also had a voluntary committee, based on county distribution, which acted as a sounding board for its activities. This committee was urged to continue its excellent work of the past 20 years and to give the board the benefit of its experiences. Similar committees of a voluntary nature, based upon county and drainage distribution, were set up by the counties in many parts of the state. Such committees have appeared before the board, and their subcommittees in the various fields of beneficial use have been developed and are working toward a common goal. These drainage subcommittees, which contain members representing all the beneficial uses, are of inestimable value to the board. One of these county committees, whose legal boundaries almost enclosed a drainage basin, had been set up prior to the board's creation, and it was decided after consulting the committee to make as complete a study as possible to establish some means of approach. This county committee had reasonably adequate funds and developed a series of the river and hydrological rainfall gaging stations as one of the first steps in its operation. The staff worked in close cooperation with the chairmen of the drainage basin committees of the Umpqua River. Following a public hearing in December 1956, in the drainage basin itself, and an on-the-spot and well guided tour of the basin, and long hours of work, a preliminary report was established on the basis of the combined efforts. Much of this work was carried on in cooperation with the various state agencies, local groups, and many of the federal agen-

cies who had done or were involved in work of the area.

The board then declared its policy with respect to withdrawals of water from appropriation for this drainage basin. Work on other drainage basins, with the aid of state and federal agencies and local committees, is now under way in order to accomplish the same purpose.

Preliminary reports are a basis for future development. In addition to the foregoing, field men attend local and statewide committee meetings of voluntary associations and deal with the federal and state agencies. The board is also participating, through the state engineer and his staff, with federal interagency committees.

It is too early to say at the present time just how effective the work of the board is. There are many conflicts born of 100–150 years of development, which in some instances would require the wisdom of Solomon for solution. The board is under no illusions as to the task ahead. It was felt, however, that at least for the beginning, the board would have a modest staff and use all of the state and federal agencies, as well as the local voluntary associations, in order to develop this work most effectively and at a price which the state of Oregon can afford to pay.

Nomenclature of AWWA Standards

For a clearer indication of the purpose of AWWA standards, the Association plans to discontinue employing the word "specifications" as a general term to describe documents that itemize the requirements (generally minimum requirements) for water works materials. Instead of "specifications," it is proposed to use the word "standard." (The term "specifications" commonly relates to an owner's or engineer's description of a specific job to be done, forming the basis on which a contract is made.)

An "AWWA Standard" is to be understood as an orderly description of the minimum requirements for the physical and service characteristics of materials and equipment for use in public water supply systems. In accordance with AWWA standardization procedure, such a document will be a "Tentative AWWA Standard" when first published. After a period of not less than a year, the word "Tentative" may be deleted by action of the Board of Directors.

Other AWWA documents are variously termed "Recommended Practice," "Recommended Procedure," and "Manual." Under these headings are documents relating to tank inspection, distribution system records, and so forth. These designations will be retained.

The word "specifications" will be deleted from current AWWA published standards as new printings are ordered.

Need for Planning in Utilizing Water Resources

M. J. Shelton

A paper presented on May 14, 1957, at the Annual Conference, Atlantic City, N.J., by M. J. Shelton, Deputy Director, State Dept. of Water Resources, Sacramento, Calif.

WITHIN a few years of the Gold Rush, Californians, and especially the agriculturists among them, discovered an irrefutable fact of nature—the state's water resources were out of balance geographically and seasonally.

It was found in those days that, while the northern streams poured vast amounts of water into the ocean, often with violence, the vast alluvial valleys to the south often were in short supply, particularly during the late summer and fall when the water was most needed. With such an unbalance, it is not surprising that planning efforts appeared on the scene at an early date.

In 1866, less than two decades following the discovery of gold, the state legislature appropriated funds for a survey of a water supply canal running south along the west side of the Sacramento Valley. This was not exactly statewide planning, but for a youthful and largely undeveloped state with a population of only 380,000, it was a significant beginning.

Ten years later, California's first state engineer, William Ham Hall, developed a comprehensive plan for the irrigation of the Sacramento, San Joaquin and Tulare valleys, encompassing the entire area known today as the California Central Valley. Hall's planning work was remarkable for he was working on an area basis in a region 500 miles long and containing more than 10,000,000 acres of irrigable land. His planning, however, has withstood the test of time, and has formed the basis for many later surveys and plans for the water development of the Central Valley. In fact, many of his basic concepts are incorporated in today's master planning.

State Water Plan

Rapid development of the central valley area, plus utilization of its water supply without a comprehensive plan for its conservation, made many serious water problems evident about 1920. These problems were aggravated by a period of subnormal precipitation beginning in 1917. As a result, the irrigation draft on underground supplies was unusually heavy, causing an alarming drop in ground water levels. Salt water from San Francisco Bay, furthermore, was encroaching into the channels of the Sacramento-San Joaquin Delta, causing their waters to become unfit for irrigation use.

Recognizing the seriousness of these conditions, the state legislature in 1921 directed a comprehensive water resources investigation. In addition to the State Division of Water Resources, many consulting engineers, geologists, economists, agriculturists, attorneys, and financiers were employed to assist with the studies. In 1931, the com-

pleted State Water Plan, called by the President's Water Flow Committee (*1*) ". . . the most carefully considered and complete plan of its kind ever drawn up," was presented to the legislature.

The initial unit of the plan, the Central Valley Project, was authorized by the legislature as a state enterprise, together with provision for its financing, construction and operation. A bond issue of $170,000,000, its estimated cost, was authorized. Because of economic conditions in 1934, the bonds were never marketed, and the state turned to federal assistance. Today the Central Valley Project is operated by the US Bureau of Reclamation.

Last year the project delivered a total of 2,753,000 acre-ft of irrigation and municipal water, generated a total of 3,251,000,000 kwhr of electrical energy, and stored 1,500,000 acre-ft of water during the disastrous December 1955 floods. It stands as a great monument to the vision of planners like William Ham Hall and his successors in California over the span of a half century.

California's Growth

Even as the first units of the Central Valley Project were being completed, California was feeling the effects of what has since become one of the greatest mass migrations in history. With the outbreak of World War II, people from all sections of the United States began moving to California, and they have not stopped coming. Equally important, industry and commerce began a strong westward movement which has accelerated with each passing year.

In 1940, California's population was 6,907,387. Today it is estimated to be 14,000,000, based on accepted standards for population estimating. In just 17 years, the state population has doubled. In some areas of the state, population has doubled in 5 years.

The effect of such an impact on water development planning cannot be overestimated. Estimates of water requirements were out of date almost before the engineers made them. Entire cities emerged where only months before bare fields existed. More and more land went under cultivation to supply the ravenous demands of these metropolitan centers.

California's planners sensed the trend even during the war years, but, with manpower at a premium, nothing could be done until the end of hostilities. As conditions returned to normal, the state legislature in 1947 directed another comprehensive water resources investigation, this time encompassing the entire state and including every possible use of water, to be staged for that date in the future when the state would, to all intents and purposes, be under ultimate conditions of development.

Although details of the plans have already been covered in the JOURNAL (*2*), a brief outline of its history and purposes is appropriate here.

Completion of Investigation

The investigations, completed after 10 years of study and expenditure of approximately $8,000,000, have been presented to the state legislature for acceptance as a broad guide within which all future water developments should reasonably conform.

The first phase of the investigations was a thorough inventory of all of the state's water resources, in which it was determined that there is, within the state, a total of 71,000,000 acre-ft of water available annually. The inven-

tory also showed, however, that the majority of the supply was available in the northern third of the state. More than two-thirds of the present and ultimate requirement was in the central and southern two-thirds of California. The figure also confirmed, on a statewide basis, what the engineers knew to be true in many localities; that the water was available in adequate amounts only during the winter and spring months, and not in the summer and fall when most needed.

The second phase of the planning was an equally thorough inventory of California's present and ultimate water requirements. This was based on known water use of today, projected cropping patterns, land classifications, and estimates of population and commerce to the year 2010. By means of these studies, it was estimated that the total consumptive water requirement will be approximately 51,000,000 acre-ft annually, with agriculture requiring approximately 80 per cent of that amount.

At first glance it would appear that the solution to the problem is comparatively simple and that there will be a fairly large margin of safety between total supply and ultimate requirement. Actually, it is a complex solution because of the intervening mountain ranges between the area of major supplies and areas of major need, because of the necessity for minimum involvement of presently vested water rights, and because of the vast new area of public policy which must be explored in entering such a great undertaking.

With these factors in mind, the planners undertook the third and final phase of the investigations: a master plan for storage and redistribution of the state's water supplies. This plan will correct the unbalances of nature and will provide water for all areas of California in which it is practical to do so. This plan, which includes 260 dams and reservoirs, power plants, pumping plants, conduits, and drainage facilities, is known as the California Water Plan.

As it has been pointed out elsewhere (*2*), it is not contemplated that all of these works will be built by the state. On the contrary, the planners foresee that all levels of public agencies as well as private enterprise will participate fully in such a comprehensive program of development.

Feather River

The first unit of the plan authorized for construction by the state is the Feather River Project, an undertaking to cost one and a half billion dollars still in the preliminary phases of construction. In May 1957 bids were opened on relocation of a major railroad and major state highway in the Oroville Dam and Reservoir area. This phase of work will require more than 2 years, and must be completed before actual construction of the tremendous Oroville Dam on the Feather River can be begun.

This planning effort is a monumental piece of work, and is on a scale which is believed to be unprecedented anywhere within state government. Tremendous and detailed as it is, the plan represents only a start for California.

Departmental Duties

As the plan was nearing completion the state administration saw the need for a strong state executive department to assume leadership in the field of water resource development. During the 1956 Extraordinary Session of the legislature, the State Department of Water Resources was created to re-

place the former division within the Department of Public Works.

Under the reorganization, which was effective Jul. 5, 1956, the new department has full responsibility for the planning, construction, and operation of water projects authorized for state construction, plus many other related functions and responsibilities.

The new department also cooperates in flood control projects with federal and local governmental units; takes responsibility for averting, alleviating, or restoring damage to property during times of emergency resulting from storms and floods, and for declaration of an emergency from such causes; compiles basic data on water resources and water use; compiles data on diversions and stream flows on the Sacramento and San Joaquin rivers and tributaries; performs maintenance work on the Sacramento River Flood Control Project; approves designs and supervises construction of all dams, except those federally owned, as regards their safety; supervises certain flood and storm damage repairs in which the state participates financially; supervises certain public water districts; reviews federal reports on flood control and water supply projects; administers state filings on water rights and provides watermaster service; makes investigations of surface and underground water supplies; makes water quality investigations; licenses artificial weather control experiments and operations; administers interstate compacts relating to water; administers the flood control fund to reimburse local agencies for their costs incurred by cooperation on federal flood control projects; represents the state on matters pertaining to the Central Valley Project; conducts engineering investigations for the California Districts Securities Commission; supervises construction of hydraulic structures for other state agencies; has responsibility for investigating and correcting beach erosion; and, in cooperation with other agencies, forecasts snow melt and other runoff.

New Problems

California must resolve other problems before it can be said that the state is well on its way to a solution of its overall water problem. Foremost among them are policy questions which, it is believed, are quite without precedent as far as state governments are concerned. There is the equally important matter of gearing planning to the constant changes of a dynamic society, particularly on the Pacific Coast, where the rate of development is so fantastic that it must be seen to comprehend it fully.

The plan must be geared to meet technological changes in the field of atomic electric power, in improved agricultural practices, and in the field of manufacturing processes and home appliances which could completely change the concept of current relationships between irrigation and other uses of water.

The plan must also be geared to future recreational requirements, which are certain to increase at an accelerated rate with the shorter and shorter work week and tremendous advances in transportation.

California has been classified for years as a semiarid state, and for much of its area, this certainly is a proper classification. One could reasonably expect that such a state would lay great emphasis on water development planning. Comprehensive statewide water development planning is now a necessity in many parts of the country

where an adequate water supply has been taken for granted. A recent statement (*3*) concerning this problem in New Jersey is highly pertinent not only to that state, but to all entities which sooner or later surely must face similar problems.

In 1954, various official proposals for state water supply action varied so widely in nature and so fantastically in cost that there was little basis for public confidence in such proposals.

In 1955, when at last a comprehensive and up-to-date engineering survey had been launched to come to grips with the water supply problem through study and planning, an ill-fated water supply bond issue proposal was prematurely put before the voters without time or facilities for adequate public understanding, without unified official backing, and without benefit of the completed engineering on which the proposal was based.

Today, there is opportunity to make a fresh start: It is now plainly evident that the state must formulate a comprehensive, statewide policy, based on engineering analysis and cost documentation, which will produce an integrated intrastate and interstate development program to meet the immediate, intermediate, and long-range needs of the whole state.

The statement pinpoints a rising public awareness of the need for comprehensive planning—and for obtaining public understanding of the problems at hand and of proposed solutions.

California, along with scores of other agencies having an interest in federal water development matters, was asked last year to comment on Senate Resolution 281. This resolution recommended, among other things, that the Congress establish an overall set of standards and criteria for judging the merits of proposed water projects.

California's comments covered a broad range of policy questions, including standards for economic justification, economic feasibility, repayment, direct and indirect benefits, cost allocations, and review of federal reports.

State Action

The state, having gone on record on matters just mentioned, is concerned with how these standards and policies should be applied to state projects. It has become quite clear that in California it is vitally important that standards be determined at an early date if there are to be water development programs determined by facts of engineering and financial feasibility, economic justification, and need. The alternate will inevitably be political expediency as the basic criterion for authorization of projects.

Various legislative actions, including the creation of a strong State Department of Water Resources, have affirmed the principle that the state should assume leadership in the development of its own water resources. This position does not preclude assistance from the federal government, from local government at all levels, and from private enterprise, all within the framework of a big plan.

Assumption of such leadership requires that the state also establish policies to implement that leadership and to coordinate the activities of other agencies operating within the framework.

Today, on the eve of its entry into major water development construction, California still does not have the answers to a great many of these policy questions, although much background work has been done and in many cases substantial progress has been made.

The State Department of Water Resources has recommended that the state adopt a policy accepting responsibility

for the financing, constructing, and operating of large interregional transfer projects, and for smaller projects in which there is definite and considerable statewide interest.

The department believes that the state should assist local agencies in the development of their own water resources through long-term, low-interest loans. The department also feels that the state should participate financially in local projects to the extent that the projects have statewide interest. The statewide interest in some instances may be the need for making the accomplishments of the local projects conform with the objectives of the California Water Plan.

In the matter of reimbursable costs, the department is still far from having a clear solution, although recommendations which amount to a refinement of the comments on Senate Resolution 281 are being studied.

The department has recommended that legislation be enacted to confirm and expand the protection of areas of water origin for the reservation of water needed for their reasonable future full development. A constitutional amendment containing such assurances should be submitted to the people in the next general election. Several such amendments now are before the state legislature.

There needs to be similar action assuring firm contracts for water from state constructed projects to areas of water deficiency. This matter also has been included in the proposed constitutional amendments now before the legislature.

Each of these basic policy subjects encompasses in itself a host of other standards and operating criteria which must be resolved within a very short time. All of them are matters for solution by the people themselves, acting through their elected representatives, on recommendations provided by the State Department of Water Resources.

If actual constructive accomplishments are to result from these studies, the engineer, his associated technicians, and related professionals such as geologists, land use specialists, economists, attorneys and others, cannot complete reports, and then sit back to await answers from the public.

Responsibility of Engineers

The engineer can produce excellent planning or feasibility reports at a cost of millions of dollars, but these will be worthless if they rest on the shelf, gathering dust. Unfortunately, that is what has happened in too many instances. The engineer has a definite responsibility in preventing such an occurrence. He must take leadership in the field of public education, clarifying the technical points which are established and translating them into terms which possess significance to the public. He must make specific recommendations which he believes are necessary to a sound, comprehensive program. He must convey to the public, in terms meaningful to the layman, the basis of the recommendations.

The engineer who, in the last analysis, has the chief responsibility in these matters, should also exert all possible effort, within the limits of his position as a public servant, to "keep the train on the track," and prevent detours which would result in a program incapable of achieving necessary objectives.

Part of that job of leadership is keeping the project moving while the people are wrestling with policy questions, so that when the debates are resolved, preliminary phases of the engineering

work will be well advanced, and projects which are needed all too soon, will be near realization. California is attacking the Feather River Project in just such a manner. There is ample precedent for this approach in the west and elsewhere.

Hoover Dam was constructed and in operation while water rights still were being, and continue to be, contested. Folsom Dam on the American River near Sacramento already has paid a huge dividend in flood control, although the question of allocation of the water stored behind the structure still remains unsettled.

California has moved to construct the Oroville Dam and power plant even though the major policy questions relating to an overall state water development program remain unanswered.

It is the view of the department that California cannot afford to wait for final answers before beginning preliminary phases of construction of the Oroville features of the Feather River Project. Relocation of utilities in the dam and reservoir site will require more than 2 years. It will be 5 years before a measure of flood control can be achieved. It will be even longer before any substantial water deliveries can be made.

Engineering studies have shown that the dam and its related afterbay and power structures are feasible in themselves as flood control and power features without the sale of a drop of water conserved in the reservoir.

This approach is an example of the type of leadership which must be assumed by the engineer and his associates during the interim before the reins of full construction are handed over to him by the people.

In addition to his direct responsibilities to the public, such as in making the factual information known and in the already mentioned examples of leadership, the engineer must investigate other facets of the problem.

Group Cooperation

There is the continuing need for working with interests at all levels of financing, both in and out of government. There is the need to relate the requirements of all agencies in competition for the same sources of financing.

The engineer must be prepared to think in terms of the taxpayer who pays the bill for the proposed development or developments, and of the ability of the water or power user to pay for the end product. His relationship to the legislature or governing body of the district or municipality is an essential factor. Inattention to any of these requirements could result in no project or in one sufficiently altered as to fail in accomplishing the objectives of which it is capable.

As all of these relate to planning, the question is raised as to where planning ends and where the construction and operation begin. Planning is obviously a continuous process, and, if it does end, an engineering organization such as the State Department of Water Resources soon will fall of its own weight and inactivity.

This principle has been well recognized in the department's work. The first unit of the California Water Plan —the Feather River Project—is barely started. The Division of Water Resources Planning, however, is already underway with more detailed planning on the next stages of the California Water Plan. Under the State Water Development Program, the planning engineers are doing more detailed exploration work to determine fitness of dam sites and locations of other works.

Whether or not any of these projects in the next stage of planning will be built, beginning perhaps before the Feather River Project is completed, depends on many factors. These include questions of need, financial conditions, and determination of policy decisions already discussed. Engineers of the State Department of Water Resources, or any other similar organization, would be derelict in their responsibility if they failed to have plans ready when they were needed and when that need instigated authorization by the proper authorities.

In compiling the California Water Plan or any similar planning effort, the engineer and his technical and professional associates can give only an orderly presentation of the future requirements as they see them in light of today's conditions. Such a plan cannot be static. It must be brought up to date on a continuing basis to meet the new requirements in light of tomorrow's conditions.

This flexible attitude toward resources planning is not the sole concern of the engineer. It falls equally to those who share the vital functions of planning. Because this is an engineering problem, however, the final responsibility falls to either the engineer as an individual, or to the engineering agency of which he is a part.

Great water projects sometimes span decades from conception to completion. A plan to meet the needs of the future will be a continuous concern, and will provide the challenge on which engineering thrives as long as civilization exists.

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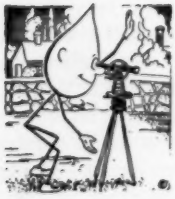

Water Works Planning in Great Britain

Geoffrey M. Binnie

A paper presented on May 15, 1957, at the Annual Conference, Atlantic City, N.J., by Geoffrey M. Binnie, Cons. Engr., London, England.

FOR some years a controversy has been going on in Great Britain between the Ministry of Housing and Local Government and water utilities on the regrouping and reorganization of the water works industry. An address by Duncan Sandys, the minister of housing and local government, at a meeting of the British Waterworks Association in November 1956 (*1*), was followed by a heated discussion after his departure from the meeting.

From time to time alarmist reports appear in the British press, particularly during droughts, and not so long ago a special correspondent of the *London Times* (*2*) referred to "the mounting demands for water to satisfy an increasing population adopting a higher standard of living" as causing grave anxiety. Yet, the same correspondent admitted that, as compared with an assumed average consumption of 100 gpcd for domestic and industrial purposes, no less than about 1,300 gpcd was lost mainly in sustaining river flow to the sea.

The average Englishman considers that water is an excellent beverage, but that for social occasions there is something lacking in it. He quite cheerfully pays 25 cents for his pint of beer, which is heavily taxed, whereas if he is asked to pay more than 7 cents per day for all the water he and his family use for domestic purposes, he usually feels aggrieved. His philosophy is that:

> Water is the best of things
> That man to man can bring.
> But who am I that I should have
> The best of everything?
> Let princes revel at the pump,
> And kings with springs make free;
> But whisky, wine, and even beer
> Are good enough for me!

Yet there is no doubt that if the national economy were reoriented so that beer was sold for 7 cents per pint and the daily domestic water requirements for 25 cents per day, water supply problems could soon be solved and there would be no further cause for alarm.

At the AWWA Diamond Jubilee Conference in 1956, John H. Murdoch Jr. (*3*) complained that in the United States the consumer has been educated by water works management to consider water cheap—"cheap as dirt."

While in these days of full employment in Great Britain it is probably true to say that nearly everybody could afford to pay more for water, at one time this was not so, and the choice lay between cheap water or dirt.

During the nineteenth century, the laboring classes of the large towns in Great Britain lived in the most appalling squalor, in narrow alleys and close courts without piped water supplies and drainage, under conditions which appear quite incredible today. Cholera,

typhoid, and other waterborne diseases were rife. Under the inspiration of the great pioneer of public health, Edwin Chadwick, the first of several investigations of these conditions was carried out by three well known medical doctors, Arnott, Kay, and Southwood Smith, in 1838; they concluded that if proper facilities, including sewerage systems and a plentiful supply of water, were provided by public authories, these evils would be removed.

From that time has developed one of the cardinal principles of British water supply policy—namely, that every citizen is entitled to an ample supply of clean safe water and that he should pay for it not in accordance with how much he uses but according to his ability to pay. Water revenues are collected in the form of a tax proportional to the assessed value of each property served, and not by metering. Generally speaking, it is only when they are used for industrial purposes that water supplies are metered.

In rural areas, also, this philosophy that every man is entitled to an abundant supply of clean, safe water has had a marked effect. Before the war there were large areas mainly or entirely without piped water supplies, but under the impetus of a clean-milk campaign and the need to increase home food production, resulting in substantial supplies being required for farms, and also as a result of government policy and legislation, a very large proportion of properties and many farms in the rural areas now enjoy a piped water supply.

In some areas served by piped water supplies, the density of population is remarkably low, and it has been said that it was only with difficulty that one responsible minister of the postwar period was prevented by his advisers from adopting as his slogan that "every house should have a tap."

Government Control

While a few private water companies, such as the South Essex Waterworks Company, still exist, the majority of the water works are owned by public authorities of one sort or another, such as municipal councils, rural district councils and joint water boards. There are over 1,000 water undertakings of all types, of which 650 serve less than 20,000 persons each.

At government level the responsibility for water supplies comes under the Ministry of Housing and Local Government, and any public water authority requiring a loan to carry out extensions or new works has to apply to the ministry for the loan. Depending upon the opinions given by his engineering advisers, the minister may refuse the loan or, after holding a public inquiry, he may grant it under his own powers. Only the more important projects, such as large impoundments, have to be authorized by act of Parliament, and they are considered by committees of the House of Commons and the House of Lords. When projects are submitted to the ministry for approval, one of the factors on which the ministry lays great stress is the conservation of the available water resources.

As regards impounding schemes, for example, some of the dams were built during the nineteenth century and too often, dams of inadequate height were constructed at the best sites in valleys, with the consequence either that part of the yield of the catchment area has been lost for all time or else that it has been made unnecessarily expensive to exploit the yield fully later. There are several examples of three or four dams having been built on the same river system, whereas only one dam need have been constructed if it had been made high enough, or had been de-

signed so as to allow for future heightening. This was in some cases due to a single authority's exploiting a catchment area without regard to its neighbors' resources and requirements. Such an authority naturally spent only the minimum sum necessary on a dam of sufficient height for its own needs, often without sufficient regard for its own future requirements.

Also, there are often advantages to be gained by integrating underground water supplies with surface water supplies, because the two types can be thus exploited to greater advantage on account of the difference in their seasonal fluctuations. For example, at the times when the water level in an impounding reservoir begins to get low and it may become necessary to impose restrictions on its supply, ground water levels in Great Britain are usually not yet at their lowest, and wells are able to yield substantial supplies, particularly if they are rested at other times of the year. Sometimes, integration can also be beneficial for water distribution. For example, some years ago, prior to the formation of a joint water board in 1946, there were no less than four trunk mains, belonging to four different local authorities, laid in the same highway in Cheshire.

The ministry has often been able to render important public service by persuading two or more adjoining water authorities to undertake a joint impounding scheme with full exploitation of a catchment area or to integrate their different types of supply and distribution systems.

Regrouping Proposals

In continuation of its policy of conserving and distributing the nation's water resources to the best advantage and also with a view to obtaining maximum economy and efficiency, the ministry, shortly after the war, arranged to have surveys of the water resources and requirements of various regions carried out by its senior engineering inspectors. Summaries of the inspectors' reports, which cover almost the whole of England and the major industrial areas of Wales, were published. These summaries were not published as the ministry's official policy, but as a guide to the water utilities in each region on the coordinated and planned development of their water resources and water supply systems. They contained proposals for regrouping of water utilities in various forms.

The ministry has not been very successful in persuading water utilities to cooperate, and while a few regroupings have taken place, the senior engineering inspectors' proposals have, in general, not been put into effect.

Under the Water Act of 1945, the minister has the necessary powers to enforce regrouping of undertakings when he considers them necessary in the public interest; but, no doubt because of the unpopularity of the exercise of such powers with some sections of the general public, he has seldom exercised them. The author knows of only one case where he has done so.

There are, however, signs that the minister's patience is becoming exhausted, and in September 1956 he issued a circular (*4*) to all water utilities which contains a clear warning that, unless they immediately give serious consideration to the needs for regrouping in their respective areas and submit their own proposals, he will start using his compulsory powers to achieve the regroupings he considers necessary.

The various possible ways of regrouping referred to in the circular are:

1. Several local authority undertakers may together form a joint

board; or an existing joint board may vary its limits of supply.

2. Two or more companies may amalgamate.

3. A local authority or a company may take over one or more neighboring utilities and so extend its limit of supply.

Generally speaking, the larger authorities are not opposed to regrouping; the opposition comes mainly from the smaller utilities. In some cases, this is from a genuine conviction that the size of utilities should be kept small so that the personal touch with the consumer can be preserved. There is also the belief that, so long as there is sufficient water to supply the district, bearing in mind the future needs, and sufficient revenue to employ a competent staff, no advantage is to be gained in making the utility larger. On the other hand, the engineering and management of these small utilities are often the responsibility of an otherwise overworked local council engineer, and do not receive the attention they need. The efficiency of utilities supplying less than 20,000 persons varies widely.

On one occasion the author advised the council of a small rural district to get a water supply from a neighboring town, but the council insisted upon having its own independent water supply scheme, out of fear of eventual incorporation by the town if the district took water from it. A similar attitude has been taken in similar circumstances by other local authorities, and there must be many cases of this sort where the smaller authorities oppose regrouping for reasons of private policy.

Necessity for Action

In order that there should be sufficient revenue for the financing of capital works and the employment of a full-time expert staff, and in order that sources and water distribution systems should be developed and integrated to the best advantage, there is undoubtedly a strong case for the regrouping of many British water utilities.

The British Waterworks Association, which can only act by consent of its members, has maintained until recently an impartial attitude in this controversy, but the January 1957 issue of its *Journal* (*5*) contains the following paragraph:

> There is much movement in the political world and events could happen, as has recently been seen, with dramatic suddenness. It might well be unfortunate for the water works industry if there was a violent change in the political scene and a different government from the present one found that the industry has made no serious effort to bring about a new pattern in spite of repeated exhortations from ministers and a clear indication from both sides of the House of Commons and the House of Lords that they consider some measure of regrouping is urgently necessary.

The Labor Party is a strong advocate of public ownership, and, while the majority of water utilities in England are already publicly owned, the party generally prefers central-government ownership and control—that is to say, nationalization—to ownership and control by local government authorities. As an alternative to nationalization, there has been some discussion at a recent socialist conference on transferring the ownership and control of all water supply schemes in England and Wales to about 50–70 large authorities, with these newly created authorities to be responsible not only for water supply, but also for sewage disposal, drainage,

town planning, police, and fire services in their respective areas. At all events, it can be anticipated that at the next general election the Labor Party will canvass for a much greater amount of centralization of water supplies.

The electorate in Great Britain is so evenly divided between the two main parties that the return to power of the Labor Party at some time seems almost inevitable, and it would appear that the British Waterworks Association is urging its members to get their houses in order quickly, lest worse befall them.

As a result of the minister's recent circular, there are signs that the regrouping of water utilities is at last receiving very serious consideration from the members of the British Waterworks Association, and many conferences among groups of water utilities are now taking place. Either by regrouping or possibly by nationalization, the pattern of water undertakings in Great Britain will undoubtedly be considerably changed in the future.

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Discussion

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Members of the British water supply industry are finding themselves the victims of many regulations and controls which, if not set aside completely or modified, give promise of disastrous effects upon future water supply for British cities.

For example, the Ministry of Fuel and Power has recently announced its intention to develop additional coal supply by operating open-cut or strip mines on the land tributary to the water supply storage reservoir of one of the very important British cities. Experience in the United States has indicated clearly that operations of this character, if not thoroughly controlled insofar as disposing of the wastes and covering over of the exposed coal are concerned, can change a satisfactory raw water source into one so highly mineralized that it can be used only if there is no alternative.

On the other hand, needed extensions to water supply systems must have the prior approval of the minister of housing and local government. This approval is not always easy to get, particularly in view of the fact that the sentiment (but not yet the regulations) of the ministry presses toward consolidation of water works supply undertakings rather than unrestricted extension of existing utilities. This particular subject was touched upon by the author.

Added to these problems is the increased use of water in Britain—not only to some degree by individual customers, but also by industries that must have water for cooling purposes or for the process aspects of their op-

erations. Related to this situation are two recent letters to the London *Times* (*1*) which are quite revealing.

J. H. Bullock, president, Institution of Water Engineers, wrote on Mar. 29, 1957:

> Mr. St. Barbe Baker, whose letter you published on Mar. 12, misunderstood the water engineers who are alleged by him to have said that in 1970 our water needs would be double present consumption, and the resources available would be halved. Though the demand for water continues to increase, there is fortunately no likelihood of an overall shortage of water in this country with its more than adequate rainfall, so long as water engineers are enabled to put in hand the engineering works which are necessary to meet the nation's needs.

The above letter brought forth a reply from Penelope Turing of Buckinghamshire, who said:

> Mr. J. H. Bullock . . . presents a reassuring picture of a part of the water problem; but it is one facet only. Certainly there will always be an adequate domestic water supply, since the life not only of the nation but of any government depends upon it. Even if this should necessitate vast expenditure in piping supplies for great distances, or converting sea water into fresh water, funds will be found for it.
>
> The larger problem which is causing serious concern to a great many people is that in the process of meeting the demands of domestic consumers and industry the balance of natural resources is being considerably damaged in many parts of the country. . . . Underground supplies are being used up more quickly than they are recharged by natural processes, and water taken from some rivers never returns to its own watershed. These are matters of fact, not conjecture. As a simple example it has been stated by responsible authorities that the water level of the London area, already more than 250 ft below sea level, is still falling by 1–5 ft annually, and this is having its logical effect on streams fed by springs in the region. Not only fisheries but everyone whose livelihood or relaxation lies in the country will be affected by this trend. The need for an informed national water policy has never been more vital.

The second letter represents the attitude of a segment of the British population which is also manifesting itself in the United States—namely, that recreation and fishing are very important, if not the most important, uses to which stored water can be put. One can easily agree with her closing sentence that the need for an informed national water policy has never been more vital. That idea has validity in the United States, as well as in Britain. It is, however, just as important in Britain as it is in the United States that a statement of national water policy not be the byproduct of the activities of some pressure group, but rather a broadly conceived appraisal of the social and economic value of water.

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Developments in Saline Water Conversion

David S. Jenkins

A paper presented on May 13, 1957, at the Annual Conference, Atlantic City, N.J., by David S. Jenkins, Director, Office of Saline Water, US Dept. of the Interior, Washington, D.C.

THE need for new supplies of fresh water and the potential effect which an abundant supply of converted salt water would exert upon the economic, political, and even military affairs of the world has been discussed elsewhere (*1–5*) and need not be further amplified here. It seems sufficient to agree that this need is real and urgent. But in seeking additional fresh water, it is recognized that conservation of existing supplies demands first consideration, and by no means may conversion be considered as a substitute for conservation. The purpose in developing additional fresh water from saline sources is certainly not to provide an ever increasing supply merely to enable continuance of present extravagances in water consumption. Prevention of water shortages, no less than cure, must be the aim. Of course, the high cost of manufactured water will discourage continued waste. Methods of removing salt from saline water by processes already in use have also been described previously (*6–9*) and will not be repeated.

Conversion Program

The search for low-cost means of obtaining fresh water from ocean and brackish waters was given national recognition by the enactment of the Saline Water Conversion Law of 1952. The objective of the program is development of practicable low-cost means of producing from sea water, or from other saline waters, water of a quality suitable for agricultural, industrial, municipal, and other beneficial consumptive uses on a scale sufficient to determine the feasibility of development of such production and distribution on a large scale. The ultimate goal is the conservation and increase of the water resources of the nation.

Although it was clearly expected by a few that, somehow, economical conversion processes for broad usage would be developed relatively soon, engineers and scientists, including the author, warned of overoptimism. Meanwhile, investigators in this country and abroad have been diligently at work exploring various avenues of approach, and the progress which has been made by them may be even more than was expected from such a small, dispersed program.

Notwithstanding this progress, it is clear that a large amount of work must be done to bring satisfactory solutions of the problem into broad use. Cost inferences for conversion obtained so far show that few water shortages can, in the immediate future, look to supplies of freshened sea water as a remedy, and that dependence must be placed for the present on wiser use of

existing sources of natural fresh water. The available data also reflect the real value of water at its source, a value now largely disregarded. Current water needs constitute a challenge to water works engineers of today, as well as to the engineers and chemists striving for the long-range goal of reclaiming saline waters for the future.

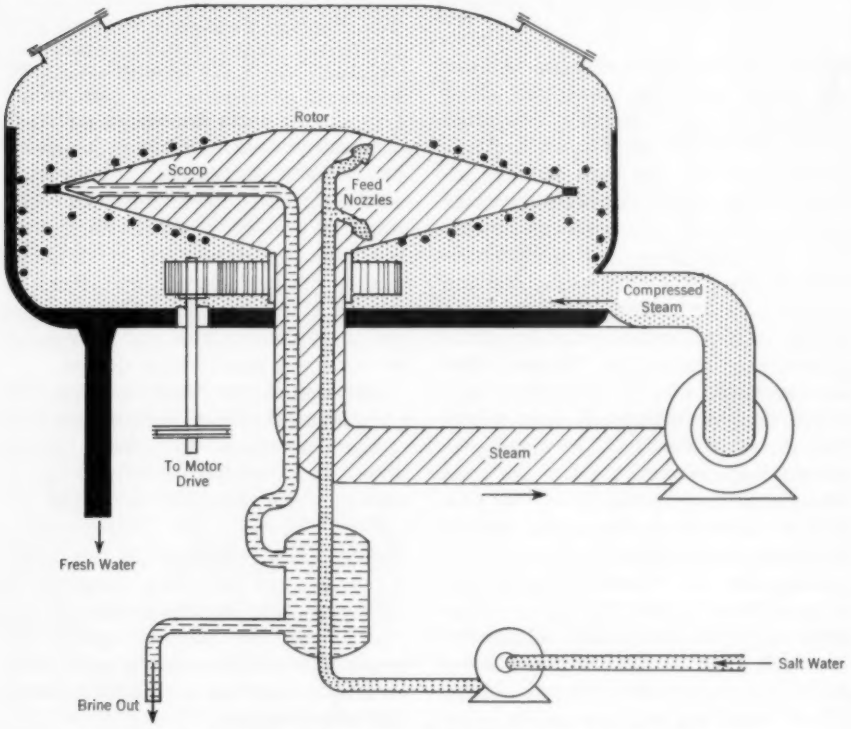

Fig. 1. Diagram of Hickman Rotary Still (Single Rotor)

In 1952, when Congress authorized federal sponsorship of research in saline water conversion, only three conversion processes were in general use, and all were exceedingly high in cost. They are multiple-effect distillation, with water cost variously estimated at \$2–\$5 per 1,000 gal; vapor-compression distillation, which was estimated to be capable of producing fresh water in projected large installations at \$1.12–\$3.00 per 1,000 gal (*10*); and ion exchange, for treating water containing very small quantities of minerals, largely for industrial uses at various costs depending on the salinity of the supply.

Because of the high cost and limited number of existing conversion processes, it was necessary at the outset to consider every possible phenomenon that might form the basis of a new process or assist in improving existing processes. It was also of importance to investigate any new energy sources

that might be utilized. A brochure (*11*) outlining the many potential processes as they appeared at that time was distributed to several thousand scientific and technical persons and organizations as a means of stimulating thought and invention. It was ideas that were most needed then, as now, and recipients of that brochure were invited to submit research and development proposals. Following the procedures of the National Science Foundation (*12, 13*) these proposals are screened and evaluated by selected groups of scientists and engineers. Proposals found technically feasible, and held necessary or desirable, are placed under research contract.

In addition to the federally financed contract research and development, a major purpose of the program is stimulation and coordination of research and development by others. This stimulation includes private industrial, scientific and educational institutions, and individuals—both in the United States and abroad. The coordination has been carried out in cooperation with a number of federal agencies, including the Department of Defense, Atomic Energy Commission, Department of Agriculture, and others; with a considerable number of private institutions in this country; and with individuals and organizations abroad. A cooperative group in Europe (*14*) has initiated four research and development programs, each participated in by a number of nations. Individual research is being, or has been, conducted on a number of processes in scattered locations from Sweden to Australia. To the greatest possible extent, information on these developments is exchanged with the Office of Saline Water of the Department of the Interior.

The results of all of the work may be summarized briefly from the four annual reports (*15*) issued to date by the Office of Saline Water. Since passage of the act more than 600 suggestions and proposals have been evaluated, some 49 research and development contracts have been entered into, and fourteen technical reports of completed research have been prepared (*16*). The scope of the research has been narrowed to six general fields which include various forms of distillation, solar distillation, electrodialysis, freezing, osmosis, and a group of other physical or chemical methods of separating salt from water.

Distillation Processes

So far, existing vapor-compression distillation equipment has presented little opportunity for cost reduction. Improved stills, however, in which greatly increased rates of heat transfer give promise of reducing such costs, in large-scale application. In one development, the heat transfer rate is increased from 500 to 3,500 Btu per hour per square foot per degree Fahrenheit through centrifugal flow of feed water in a thin film over the surface of a conical rotor. Fig. 1 illustrates the Hickman still utilizing this principle. A pilot plant of this type, designed to produce 25,000 gpd, is under construction (Fig. 2). From the design data it appears that, if the forthcoming tests of this equipment show that larger equipment of the same type is feasible, water costs may be reduced greatly below those projected today, particularly with the advantages of mass production.

An attractive multiple-stage distillation process using long-tube vertical evaporators of the kind employed in the salt industry has been proposed by

W. L. Badger of Ann Arbor, Michigan. In this cycle (Fig. 3) sea water is passed through a series of evaporators under reduced pressure and temperature, utilizing either heat applied directly or that recovered from the exhaust of a steam-powered electric generation plant. The cycle requires completely scale-free operation and the economy derives from the use of low-cost scale prevention and low-cost (ferrous) metals. Badger has estimated that if scale can be prevented economically, without excessive acid feed treatment which requires non-ferrous metals, it might be possible to produce water by the process at about $0.40 per thousand gallons—without the cost advantages of utilizing heat from power generation. He also estimates that if, in addition, power can be sold from a multipurpose plant, the water cost would be reduced appreciably. This is a projected process; it has not been built. Similar equipment has been built and used on sodium chloride brines. A test unit is being constructed * and will be tested on sea water for the purpose of developing scale prevention techniques. If such techniques can be

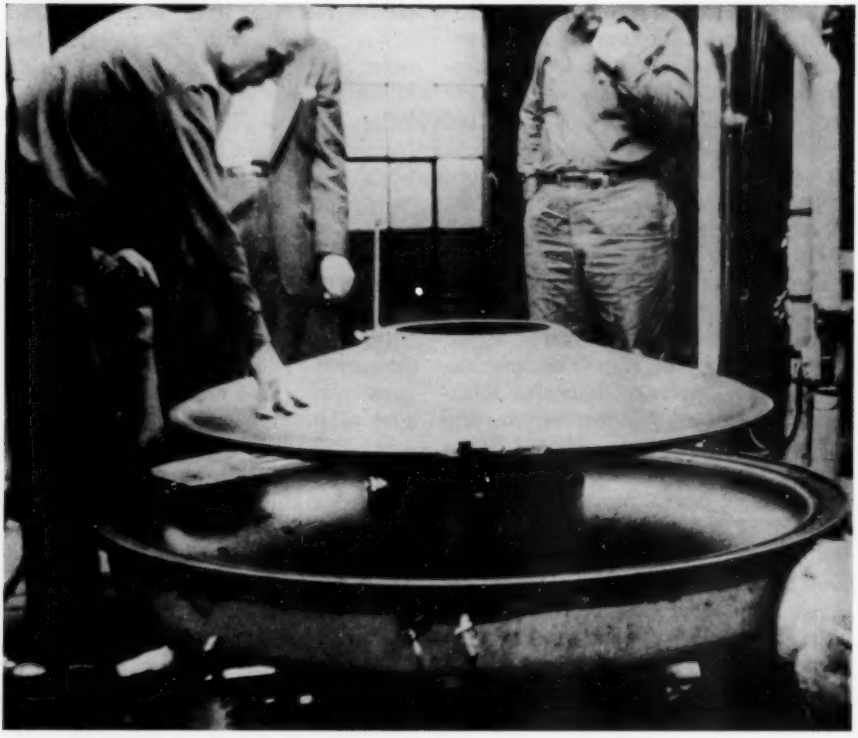

Fig. 2. Multiple-Rotor Assembly of Hickman Still Being Installed

* The unit is being built by the Whiting Corp., Harvey, Ill.

developed, further work on the process may be undertaken.

Economical use of solar heat for distillation depends largely on low-cost construction of the necessarily extensive plant required for any substantial output with single-stage stills (Fig. 4). Production rates are 1 gpd for every 5–10 sq ft of exposed surface under climatic conditions found in the Southwest. The size of plant required, and the unknown costs and difficulties of steam-driven vapor-compression cycle, design of low-temperature vacuum-flash distillation in connection with the so-called "low thermal difference" system, and comparative analysis of several distillation cycles. Developmental work is being continued on several of these, although in cases where solutions to problems have not been reached, the work has been halted for the present. For example, critical-pressure distillation was shown to be technically feasi-

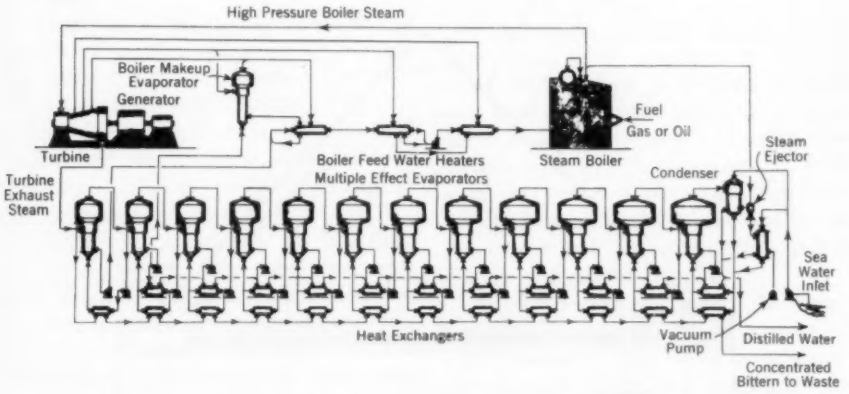

Fig. 3. Flow Sheet of Multistage, Long-Tube, Vertical Distillation Plant

Layout is after cycle of W. L. Badger and is shown combined with steam-driven power plant.

plant construction, maintenance, and operation are recognized as the critical factors in the utilization of this process. Developments in multistage solar stills, on which very limited—though promising—work has been started, are needed to reduce the required area where land cost is high.

Other research in distillation sponsored by the Office of Saline Water includes forced-circulation and dropwise condensation, separation at high temperature and pressure in the critical range of salt water, design of a large

ble and appeared economically attractive. As scale formation has not been overcome, however, further work on this process must await development of scale prevention techniques.

Electrodialysis

Electrodialysis (Fig. 5) for separation of the salt ions from the water has been demonstrated to be physically possible, in both the laboratory and the field, with either sea water or brackish water. Pilot plant field trials with brackish waters indicate projected

large-scale costs of $0.80–$1.00 per 1,000 gal for equipment developed in the United States. Cost estimates of similar processes being developed abroad are much less. The cost of sea water reduction to the potable water limit of 500 ppm is likely to be impracticably high, although greatly improved membranes being developed here and abroad may reverse this forecast.

an ideal arrangement of these units could provide water at $2.30 per 1,000 gal. It was clearly indicated that new approaches for utilizing freezing phenomena could be developed.

One such new method would combine freezing and evaporation (Fig. 6) to achieve demineralization. This type of process is under investigation. A second bold new approach to the freez-

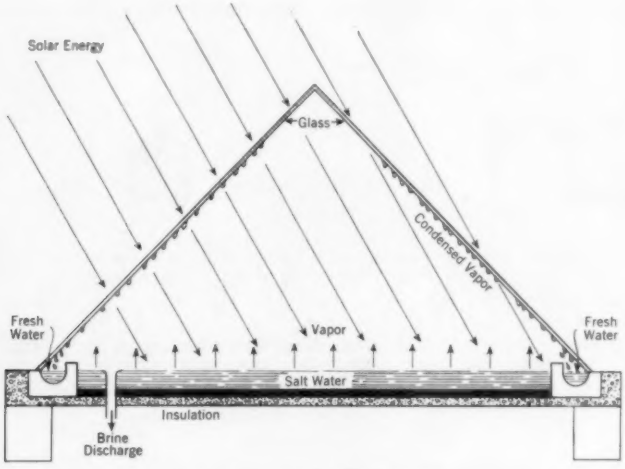

Fig. 4. Simple Solar Still

Vapor formed by evaporation condenses on underside of glass and flows into trough. Improved designs using the same principle include ground level stills, plastic sheets instead of glass, plastic evaporation pans, and multieffect stills.

Freezing

Freezing processes have certain potential advantages when compared to others, including less tendency toward scaling and corrosion, because of the low temperatures involved. Under sponsorship of the Office of Saline Water, the University of Washington investigated the demineralization potentials of existing commercial types of freezing units and concluded that

ing process is currently being studied by Battelle Memorial Institute. This process is called zone freezing. The investigation to date has been limited to evaluating critically the ability of this technique to remove salt from solution, and to collecting data which would suggest whether or not engineering development is warranted. Other ideas for increasing crystal size and facilitating the ice-brine separation phase

are being experimentally evaluated by the Applied Science Laboratories of Pennsylvania State University.

Nuclear Adaptations

Combinations of saline water conversion cycles with nuclear power generation plants have been suggested as another means of reducing energy costs. But the cost of electrical power or heat from nuclear energy will have to become competitive with that from other energy sources before this may be realized.

There may be ways, however, of achieving certain operating advantages by using the reactor primarily to produce low-temperature steam or by utilizing the energy from the electric-generating reactor during off-peak load periods. Studies of possible multipurpose advantages have been actively considered for some time by the Office of Saline Water. In cooperation with the Atomic Energy Commission, a project for a preliminary cost analysis of certain combination reactor and distillation equipment has now been started.

In addition to those processes previously mentioned, several others show promise and are being actively investigated. Work on the osmionic process, being developed by Southwest Research Institute, is progressing, and an experimental model capable of producing 240 gpd is being fabricated and will be tested this fall. As a result of recent work at the University of Florida, it is anticipated that an improved semipermeable membrane can be prepared having an increased flow rate and greater durability, which may greatly benefit the reverse osmosis process. An investigation of a process, called transport depletion, has recently been initiated.

Precipitation of salts, the use of ultrasonics, gravitational diffusion, hydration, use of the streaming potential, electromagnetic effects, and electrostatic effects have received considerable attention and some theoretical study, but no feasible means of applying these principles to the problem have been proposed. Limited work is underway on other borderline processes, such as biological membranes, and molecular oil films.

Conversion Costs

In estimating future costs of water conversion, it is necessary to bear in mind that present projections of costs are mere inferences based on incomplete small-scale work. Specific cost figures adapted to the practical decisions of water works engineers must await much additional investigation in laboratory and large-scale tests, and in design and application.

Any statement concerning the future costs of conversion based upon such partial results is obviously treacherous even though all limiting conditions are carefully specified. Statements inadvertently taken out of context, or with the essential qualifications deleted for lack of space, can and do cause misunderstanding.

The extreme variations in method of estimating costs of water produced by conversion processes made it impossible, at first, to arrive at any reliable comparison between processes or between conversion process costs and other water costs. Hence, it became imperative to reach agreement on a standardized procedure for estimating costs of saline water conversion processes from a fixed set of assumptions. That has now been done and the standardized cost estimating procedure in

use is reasonably conservative (*17*). A few of the factors considered in such a comparison are:

1. All essential plant costs, service facilities, and engineering costs
2. Amortization based on 20-year plant life
3. Interest at 4 per cent
4. Power at 7 or 5 mills per kilowatthour

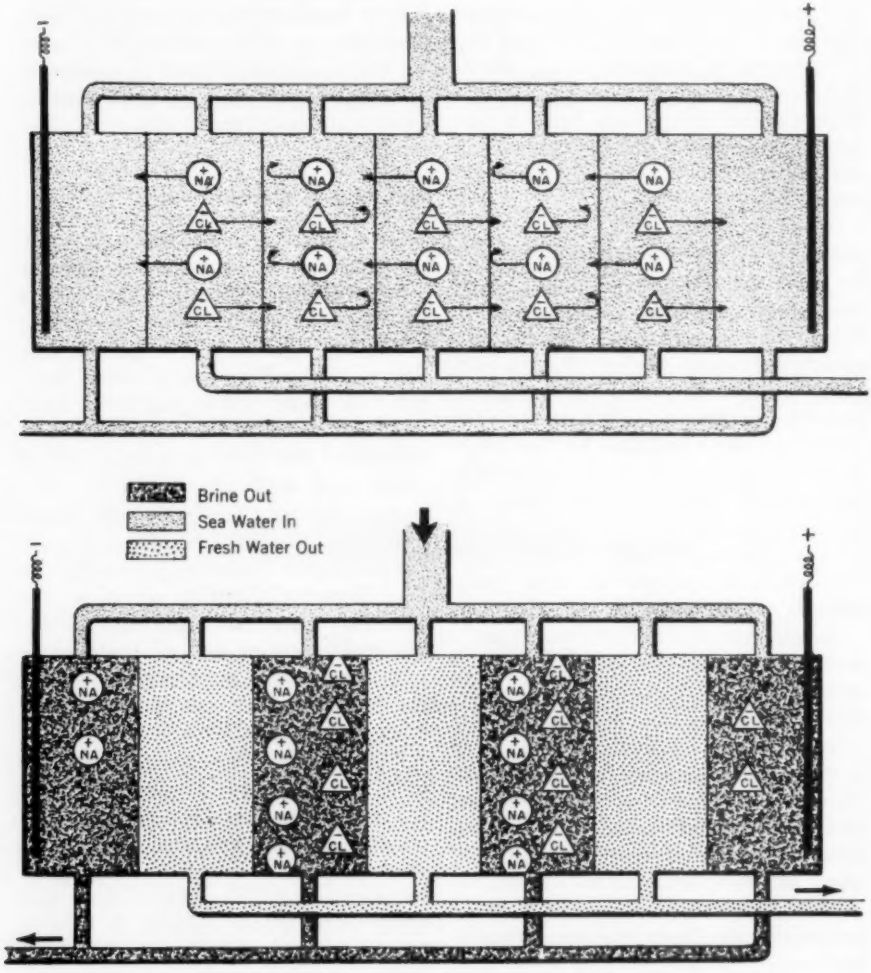

Fig. 5. Diagram of Electrodialysis Process

Membranes permeable respectively to anions (Cl^-) and cations (Na^+) are arranged alternately between electrodes, with water flowing in intervening spaces. Top view is of unit at instant current is applied, with arrows indicating direction ions move. With continued current and water flow (lower view), salt is transferred to alternate cells, leaving desalted water in cells between.

5. Heat at $0.25 per 1,000,000 Btu
6. Land costs at $3 per 1,000 gpd capacity
7. Storage for product water (10 days)
8. Steam at $0.55 per 1,000 lb.

As a result of applying this standardized yardstick to the many and varied computations that have been submitted by research contractors and others, cost inferences of future large installations, in general, are considerably higher than before.

Since 1952, with the exception of one membrane process which appears better suited to treatment of brackish waters than sea water, no new conversion process has been developed to the production stage. This necessarily means that ultimate water costs cannot be estimated closely at this time. Further, the experience with the membrane process has shown that custom-built apparatus involves equipment costs excessively high as compared with estimated future costs after the market will have expanded sufficiently to justify mass production methods.

The overall results of the program up to this time forecast substantial reduction of the cost of sea water distillation by either fuel or solar heat and demonstate the effectiveness of electrodialysis for desalting brackish waters. They also indicate promise in a number of other processes such as freezing, osmosis, possibly solvent extraction, and others.

Future

Present construction of several pilot plants, to be followed by extended test operation, should, in the near future (1–3 years), provide important data to correct or confirm some of the present results. The conversion process development program is still in its infancy, and its further progress will define the useful range of application of desalination processes as well as the lowest costs attainable.

If an ultimate large-scale cost figure of $0.30 or more per 1,000 gal is tentatively set as a not impossible goal of demineralization costs, it will be clear that advance planning in many fields of municipal and even agricultural water supply must eventally undergo radical revision.

It is also equally clear that industry can no longer count on obtaining new supplies of fresh water in large quantities at prices presently paid by many large industrial water users. Those prices are sometimes less than the mere distribution costs of municipal water systems, and take no account of the value of the water at its source. Past assumptions that fresh water wherever it occurs in nature represents no value, but may be taken for use by anyone at the bare cost of diversion, cannot be maintained in the face of water shortages and active search for sources of additional water in the uplands or the sea.

Water Value

Realization that replacements of naturally fresh water by water reclaimed from the ocean will involve costs several times those now paid by many industries, should emphasize the fact that fresh water is a highly valuable resource, and one which the nation cannot afford to waste. Perhaps one outcome of the work of the conversion program to date which has major significance is this emphasis which it places on the value of fresh water. It is obvious that any essential resource such as fresh water is worth what it costs to replace or supplement, and it is equally obvious that this same value also determines what can justifiably be spent in preventing or eliminat-

ing the waste of that resource. In this sense, prevention of water waste may well justify the expenditure of a good many dollars for each acre foot saved.

These conclusions address themselves directly to the water works engineer. He is familiar with the fact that, year by year, nature provides an ample supply of fresh water, and that only a small fraction of this supply is required for the nation's proper uses. Yet, a large part of this natural supply is not conserved or stored. He knows that flood runoff from storms and spring thaws is hurried on its way to the sea as rapidly as extensive channel works can bring this about; that the use of many streams is effectively destroyed by their pollution with sewage; and that systematic ground water recharge, as well as use of sewage effluents, is all but universally neglected. The principle that fresh water should be restricted to uses yielding a return at least equal to the value of the water is now coming to be recognized.

Conclusions

It is a reasonable finding from the work done so far that in much of the United States many near-future shortages of fresh water may be relieved more expeditiously and cheaply by curtailing water waste than by attempting to supplement supplies by sea water conversion. If replacement by conversion is used as the criterion, waste prevention or supplementary supplies may warrant expenditures of $0.30 or more per 1,000 gal, and many water rate schedules may require upward revision to bring prices on a level with distribution costs while reflecting, at least to some degree, the value of water as measured by the cost of replacement through conversion of saline waters.

In view of the possibility that the price of fresh water reclaimed from the sea may, under even the most perfect processes of conversion, be higher than many current water prices, it is natural to ask how much the water user can

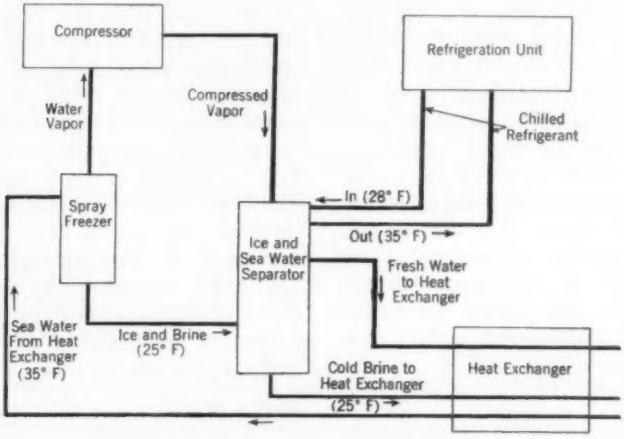

Fig. 6. Layout of Freeze-Evaporation Process

be expected to pay. When he needs water, either to tide over a temporary shortage or to provide a permanent addition to his supply, what price can he afford? Early in its work, the conversion program adopted the figure of $40 per acre foot for irrigation water and $100 per acre foot for municipal water as a goal of conversion cost. For present purposes, however, water works engineers are better able than the writer to estimate both the present and future cost of fresh water conveyed from distant points and the price which users may expect and be able to pay in the light of rising costs and anticipated increases in population and industry.

Obviously, processes whose cost reductions are partly dependent on the use of large-scale units or on mass production techniques should be considered for application to future large public water supplies. This would include the distillation, freezing, and electrodialysis techniques. Solar distillation for use on a large-scale basis will depend on climate and, in the absence of an effective heat recovery system, upon the availability of relatively inexpensive land. The osmotic, osmionic, and solvent extraction processes are not advanced far enough to warrant a forecast of specific applications, although they are technically promising.

Five years ago, W. L. Langelier said (*18*): ". . . engineers and chemists will unceasingly pursue their efforts to solve this all-important problem of increased water supply for areas of low rainfall." That statement is appropriate today, but, meantime, water works engineers will have much to do in extending supply sources, reducing water waste, and modernizing rate structure on a realistic basis.

With regard to the future costs of saline water conversion, if the research is successful, water should be available from sea water within 5–15 years, at prices which many industries and some municipalities can pay. Some water from brackish waters should be available for irrigation somewhat earlier. If new, scientifically sound ideas are developed, that time may be shortened materially.

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Discussion

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The shortage of water throughout the world, and especially in arid and semiarid regions, is a problem which must be solved to a large extent by the conversion of saline waters into usable fresh water. The accomplishment of this aim has very great appeal to all people. This hope is not of recent origin, but has extended over the ages. Unfortunately, there is much misinformation as to how this goal may be reached and few people have a real concept of the complexity of the problem—both from engineering and economic viewpoints.

As has been stated, the initial stage of the program was necessarily broad, to include all existing or potential means of conversion. It has been imperative to conduct such a fact-finding survey in order to choose intelligently those processes which would justify further study, laboratory experiments, and, eventually, installation of moderate-scale pilot plants where the economics could be more realistically evaluated. The survey and small-scale experimental work to date have been productive in providing a clearer understanding of the several types of treatment suggested by various individuals or groups. Now that this preliminary work has been largely completed and the assembled data have revealed the practical processes, the time approaches when it will be desirable to build pilot plants large enough to provide reliable engineering data. As these data become available, it is to be hoped that they will justify one or more commercial installations for the conversion of saline water. It is gratifying to us who have watched the progress of the program from its beginning to hear the report that several of the processes are already approaching the pilot plant stage.

Inland Use

There appears to be a widespread belief that the demineralization of saline water is limited to seacoast areas where salt water is available in unlimited quantity. This is not the case, however, as there are, in many inland areas, voluminous quantities of saline water available from underground sources or from surface supplies. Such water supplies are generally found in arid regions, and, therefore, the production of fresh water in such areas has great appeal. If fresh water were available, many of these regions could be converted from wastelands into habitable areas.

Allocation of Converted Water

How the water so produced may be utilized will depend entirely upon local

conditions. Domestic requirements for the support of life must, of course, have first priority on such water. After satisfying human needs, however, the optimum development of water resources will be accomplished only when the available fresh water, either natural or converted, is allocated to the most beneficial purposes. It is imperative that all competitive water uses be considered in light of comparative economic returns. This is a fundamental principle which should guide all developments in this field.

In the allocation of scarce water resources, consideration should be given to the various classes of water available and to the quality requirements for different uses. It must be obvious that high quality water should be selected and provided only for those purposes where such supplies are imperative. Where the activity can tolerate lower grades of water, full advantage should be taken of corresponding supplies, leaving the more costly converted water for more exacting beneficial uses.

The statement regarding conservation of water is to be recommended for careful consideration, and the writer wholeheartedly supports the comment, "It is obvious that any essential resource such as fresh water is worth what it costs to replace or supplement, and it is equally obvious that this same value also determines what can justifiably be spent in preventing or eliminating the waste of that resource. In this sense, prevention of water waste may well justify the expenditure of a good many dollars for each acre foot saved." There are many ways in which water can be conserved, and the greatest conservation can be effected in those pursuits in which water is nonconsumptive.

Prospects

The author has wisely stressed caution against overoptimism on the immediate production of low-cost fresh water from the sea or other saline supplies. Regardless of this caution, it may be predicted that the cost of conversion will in time become economically feasible for selected uses throughout the world. Saline water conversion is already being practiced in a relatively few isolated cases, and with further development of techniques costs may be reduced well below present levels. There is hope for the creation of dual-purpose plants designed to produce both electric power and fresh water by the utilization of byproduct heat or off-peak power. Such a plant, using either conventional or nuclear fuel, offers an intriguing possibility. As a matter of fact, a salt water conversion installation utilizing waste heat from a power generating station has recently been recommended for solving the problem of fresh-water shortage on one of the island possessions of the United States. Congress has been requested to make an appropriation of $1,600,000 to carry out this project. Studies are being undertaken in several other locations to determine the practicability of combining the demineralization of saline water with nuclear power production.

In summary, it is the writer's considered opinion that the work of the Office of Saline Water is a timely and potent factor leading to a partial solution of water shortage in many arid lands. From the results already obtained, as reported by the author, it can be concluded that the comprehensive research approach to the problem is intelligent and should be continued and expanded as rapidly as possible.

Off-the-Job Safety Programs

George C. Sopp

A contribution to the Journal by George C. Sopp, Joint System Head and Asst. Mgr., Dept. of Water and Power, Los Angeles, Calif.

AMERICAN industry is crying for more workers, technical, skilled, or unskilled. Screaming headlines in full-page newspaper advertisements make a most appealing and persuasive sales pitch. Industry is now going to the colleges and universities and making direct contacts with upperclassmen and others. Campus drives to siphon off needed manpower ahead of competitors have produced elaborate and expensive recruitment brochures describing the advantages of employment and the opportunities for advancement in the respective companies. At the same time, however, industry has been blind to a great source of productive manpower which it already has but the benefit of which it is constantly losing because of the staggering toll of off-the-job injuries.

Industry is bidding higher and higher, trying desperately to get the personnel it needs to design its products, operate its machines, man its assembly lines, and type its letters, while in 1955 alone, within industry and by off-the-job accidents in the United States, 93,000 people were killed and over 9,350,000 were injured.

Imagine the extent of suffering and heartache to the even larger group related to those who were killed. But that is not the only loss, for business and industry have also been permanently robbed of experienced, trained, and skilled men and women, to say nothing of the 9,350,000 injured last year, most of whom were employed—a staggering figure of productive labor lost to business and industry either permanently or temporarily.

A great source of labor which industry needs can be uncovered through a safety program designed to reduce off-the-job accidents, if diligently entered into by management and programed with the same tenacious energy which they now use in solving engineering or financial problems.

Industry, with the coordination of effective safety programing and the cooperation of management and labor, is achieving a large measure of success in reducing death and injury *in* industry. Even so, last year there were 14,200 persons killed and 1,900,000 injured. But efforts *are* beginning to produce a higher level of achievement in reduction of industrial injuries.

But what of off-the-job injuries—the big problem in safety? Is there a reaching out toward this important second plateau?

Off-the-job accidents last year killed 79,100 people in the United States and injured 7,450,000. Eighty-five per cent of all deaths were a result of off-the-job accidents.

These are stunning statistics—so great that it is almost impossible to realize that we allow them to continue to happen year after year. Certainly this is neither humane nor economical.

Accident Costs

The National Safety Council (*1*) has shown that the cost of all accidents in the United States, both on and off the job, for 1955, was $10,300,000,000. This staggering figure represents many things in terms of community needs. The public school systems of the United States—from kindergarten through junior college—including all operating expenses, such as equipment, maintenance, and salaries, cost, for one year, $7,902,702,000. This could be paid out of the cost of accidents and still leave almost $2,397,298,000 which would pay 42 per cent of the cost of operating all the hospitals in the country.

From another viewpoint, in 1955, advertising of all types, including national and local newspaper, magazine, radio, television, and direct mail, reached a record high of $9,029,000,000. This was still $1,271,000,000 less than the cost of accidents during the same period.

Today, all but a very few in industrial management are convinced that industrial safety is a real source of revenue and a truly humanitarian effort. A glance at the period just before the start of the industrial safety program will be instructive.

Growth of Safety Philosophy

At the close of the 19th century, and while the start of the new 20th century was still being celebrated, the impact of the industrial revolution in America was just beginning to be felt by all Americans and many Europeans.

The impact of any force usually produces pain, and, in those early days, the pains were growing pains. American industry was young, but it was strong, active, progressive, and eager to get into its stride of heavy production. In this strength and eagerness lay one of its greatest weaknesses—the failure, at that time, to consider the health and welfare of the toiling hands that turned the wheels, pulled the levers, and manned the assembly lines.

Too great a number of these toiling hands were being partially or totally disabled, temporarily or permanently. Not only were the grinding gears, the fiery furnaces, and the great forging operations causing horrible pain, hardship, and death to the workers, but slow, silent and creeping death waited, watched, and took its frightful toll in the form of silicosis, the result of breathing finely powdered quartz—so fine that a single particle would remain suspended in still air for a full hour or more. There was also loss of teeth and hair and even blindness from the inhalation of metallic fumes, mists, and vapors, and the absorption of raw, poisonous chemicals that left men helpless invalids.

It was a black picture that was painted on the pages of the nation's history during its early industrial growth —one which produced a revulsion in the hearts and minds of many Americans whose influence was felt in the churches, in government legislative halls, in labor organizations, and in the newspapers of the country.

Evolution of Legislation

They asked for a law which would require industry to take some of the burden of these injuries from the public, and, by organizing their effort and concentrating their will in and on the legislative bodies of the various states, the first employer liability acts were proposed. Although there were no real teeth in these first acts, they marked the beginning of a new era for the

workman. Employers wanted no part of it. They said it would be "too costly" and "ruinous," and the sad part was that many employees who were injured felt that their injuries had just happened and that nothing could be done about them.

There were many within the ranks of the employers who were convinced that any law that made industry responsible for the medical care and money compensation of a worker after an on-the-job injury would mean financial disaster. Believing that the labor supply was unlimited and inexhaustible, they argued that the worker accepted the risk when he placed his name on the employment roll, and that his years of training and experience adequately equipped him to protect himself at all times. After all, labor was plentiful and the hazards of the job were compensated for by wages; "Let the employees save some of their wages—just in case." Furthermore, it was felt, there was no need to pay any kind of compensation because there was no law that really required the employer to do so.

All arguments of the opposition, however, seemed to have the opposite effect, tending to crystallize and intensify the demand, which had become a vital political as well as a humanitarian issue. After many trials and many errors, acceptable compensation and compulsory insurance laws were passed, gradually increasing the ranks of one of the greatest organized movements in the nation's history for the benefit of the workers of America.

Any law, to be effective, must provide funds for its enforcement and penalties for its violation. These aspects are usually clear and distinct, and need no interpretation; but the third factor—the law's requirements—is often much more liable to misinterpretation. Agencies, therefore, were set up to enforce the requirements that machines and operations be guarded.

Insurance companies provided coverage to spread the risk, but the costs were even greater than the insurance companies had foreseen. They helped, however, by forcing employers to guard their machinery—that is, to start a safety program.

Loopholes were found in the laws, but these were plugged. The safety program became almost a necessary evil, until some cost-conscious employers found out that safety would pay, would increase profits, would help raise dividends, and last (and almost least in those early days) would save human lives and reduce human suffering.

Today, the value of an industrial safety program is an established fact. Today, the public would not permit an industrial firm to continue if it had a series of bad accident experiences. In addition, the employer's insurance carrier would cancel coverage unless good safety practices were established.

Safety has come far. Today, it is good public relations to have and to advertise a good safety program, and a good safety record is announced proudly as an achievement.

Costs to Industry

The beachhead which has been established, although commendable, is not enough, for the second plateau—the big problem of off-the-job safety—must be confronted.

Many have said, "This problem is someone else's headache; it's not a direct concern of business and industry." But this is wrong, for it is, and must be, the responsibility of industry, being, as it is, directly and intimately connected to industry's production and in-

come. The magnitude of the problem can best be comprehended when it is remembered that 85 per cent of *all* accidents are off-the-job accidents, and that their cost, last year alone, was more than $7,308,000,000.

It can be asked if this is a field for concentrated industrial effort—if this is another burdensome cost with which to saddle industry, or whether there is a dividend for industry, too, for its operation in this field.

When an employee who has cost industry thousands of dollars to train and equip is killed or crippled by an off-the-job accident, surely industry suffers a loss. If the injury or death is suffered by a member of the employee's family, although not directly injured, the employee may be required to stay at home for a few days. If he loses no time, and continues to work, there is the question of whether he will keep his mind on the job or whether his distraction will cause spoiled material, broken machinery, or an industrial injury to himself.

It is interesting to consider what the effect would be on industry if the tremendous cost of off-the-job accidents now being paid in taxes, in contributions to "worthy" causes, and in contributions of organizations supported in part by industry, were suddenly extracted from each industrial organization and paid directly for off-the-job accidents. It would constitute no more money than is now being paid, but payment would be made in one lump sum per year and would be earmarked as such. There would be an abrupt and rude awakening to the fact of these wasted dollars, and industry would at once put into motion effort equal to or even greater than that which has already so effectively lowered the industrial accident experience.

The need for off-the-job safety can be read from the pages of every newspaper, seen at any emergency hospital, or witnessed on any highway. Table 1 lists a few of the causes of death in off-the-job accidents in homes.

Dividends

Since industry is paying for these off-the-job accidents it would seem logical to get some good public relations value from the money that is spent. An employee campaign on off-the-job safety will pay dividends. There are two ways in which industry could better spend its dollars to make direct savings than by decreasing the absenteeism due to off-the-job injuries and sickness. The investment would produce the added benefits of an enhanced public relations and improved employee relations.

TABLE 1

Some Causes of Death in Home Accidents, 1955

Agent	Number of Deaths
Falls	14,000
Fire burns	5,400
Mechanical suffocation	1,200
Poisons, solid or liquid	1,050
Poisonous gases	800
Firearms	1,100
Others	4,450

The effect, from a public relations viewpoint, when an industrial organization uses its knowledge of accident prevention to tackle the problem of off-the-job safety should be considered. Giving each employee an attractive booklet on off-the-job safety, sending to his home a safety cartoon folder which describes hazards in the home or on vacation, or sponsoring a program of first-aid training on the com-

munity level—all such activities raise an organization's public relations standing, enhance community appreciation and acceptance, and establish a oneness with the community.

Some of the many values to be derived from an industrial off-the-job safety program are:

1. Reduction of absenteeism
2. Opening of a new source of manpower
3. Conservation of existing manpower
4. Lowering of costs of operation
5. Improvement of public relations.

Industrial companies can do several things to foster off-the-job safety. Through their own employees and families, pamphlets and posters relating to off-the-job safety can be distributed. These can be obtained from the National Safety Council and from insurance companies, or they can be produced individually. Safety slogan contests can be held in the community and home safety committees can be formed and encouraged. Cooperation with some of the following organizations would be valuable and appreciated: colleges and universities, fish and game departments, women's clubs, parent-teacher associations, health departments, fire departments, the Boy Scouts of America, the Girl Scouts of America, 4-H clubs, and local safety councils.

Safety should be instilled in the minds of American youth to the degree that it recognizes that injuries received in play and at home are *not* to be considered as just the inevitable and necessary inconveniences of living, but the direct result of carelessness or lack of judgment which can be avoided.

Conclusion

Every half-hour in the United States, six people die and 525 are injured in off-the-job accidents. These people are lost to industry, either permanently or temporarily. Yet, in spite of industrial mechanization and the advance of automation, the people of industry, the workers, are more important today than ever before because of their production knowledge and technical skill, as well as for the training which industry has given them—training which costs industry hard dollars when they are not on the job.

No piece of machinery is too big nor any operation so important that industrial management would not gladly stop production if it would save just one human life. Yet, in the last 30 minutes, six have died and hundreds more been injured.

Reference

1. *Accident Facts—1955.* Published annually by the National Safety Council, Chicago, Ill.

Court Opinions on Pipeline Breaks

John H. Murdoch Jr.

A paper presented on May 13, 1957, at the Annual Conference, Atlantic City, N.J., by John H. Murdoch Jr., Consultant, American Water Works Service Co., Philadelphia, Pa.

THIS paper is intended to present a brief statement of the law in the United States on the liability of public water supply agencies for damages occasioned by pipeline breaks. Since federal or constitutional questions are not involved, the law on the subject is law in the United States, not United States law. It is law founded upon and contained in decisions of state rather than federal courts, and variations are to be expected; but there is enough agreement to make possible such a brief summary statement as is here attempted.

On one point there appears to be uniformity of opinion. There is no distinction between publicly and privately owned water supply systems as to liability for damages for pipeline breaks. Privately owned systems are, of course, business enterprises, and as such are responsible for the actions or neglect of their officers or employees in the performance of their duties. When a municipality or other governmental body, except a state or the United States, undertakes to supply water to the public for commercial, domestic, and industrial purposes, and to charge for such service, the courts hold that it is engaged in performing a business function and acting in its proprietary rather than its governmental capacity, at least so far as to make itself liable for line break damages. It is beside the point here, but fire service is held to be a governmental function. It will be remembered, also, that the US Supreme Court held a number of years ago that the salary of the chief engineer of the New York City water system was not subject to federal tax because that system was performing a governmental function. In spite of these quirks of the law, the fact is that as to line break damages there is no distinction between publicly and privately owned water supply systems.

Types of Decisions

There appear to be three types of decisions in which the state courts have dealt with claims for damages caused by line breaks. At this point these three types will be designated and described only to the extent required to indicate the essential distinctions between them. Later each will be explained in a little more detail after certain definitions essential to an understanding of the various courts' views have been stated.

The courts of a great majority of the states hold that a public water supply agency is liable in damages for injuries or loss caused by water escaping from pipeline breaks only if it is proved that negligence chargeable to the water supply agency was the proximate cause of the loss. The point in this type of decision is that negligence must be proved.

The second type might properly be designated as a variant from the first. It may be called the *res ipsa loquitur* type. Here again, negligence is an essential element. The courts have held, however, that, where it appears that an accident would not ordinarily occur without negligence, the fact that the pipeline was in the exclusive possession and control of the defendant agency and that it has exclusive knowledge of the care exercised in the line's installation and operation is sufficient inference of negligence to shift the burden of explanation to the defendant and to require that the case be submitted to the jury.

The third type follows an English case of the 1860's known as *Rylands* v. *Fletcher*. This did not involve a pipeline break but rather the flooding of a mine. Water had escaped from a reservoir into an abandoned mine directly underneath and had drained from there into an adjacent working mine where the damage was done. The English court held that there was no negligence involved, but that one who maintains on his own property a thing which would cause injury to others if it escaped is liable if the escape occurs even though no negligence exists. The doctrine has not been widely adopted in the United States, but the courts of Minnesota have applied it to water pipeline breaks.

Essential Definitions

Negligence is the failure to observe for the protection of the interests of others that degree of care, precaution, and diligence which is demanded by the circumstances, whereby others suffer injury. Otherwise stated, *negligence* is conduct which falls below the standard established by law for the protection of others against unreasonable risk of harm.

Standard of conduct established by law is that of a reasonable man under like circumstances.

Reasonable man, in water works cases, would be a well trained water works man.

Unreasonable risk is one in which the dangers involved outweigh the value of the conduct.

Thus, there is negligence in pipeline break cases if servants, agents, or officers of the water supply agency do not act as well trained water works men would act under like circumstances and if their conduct creates risks of harm to others which outweigh in value the social advantage of having a water pipeline in operation in the particular location.

Majority Type

The courts of the states which, in pipeline break cases, follow the rule that the public water supply agency can be held liable for damages only when the claimant proves negligence have had before them a very great variety of factual situations. It seems inappropriate in such a presentation as this to cite cases and to set forth the facts which led to the court decisions. Each water works man, in considering claims for damages in line breaks and determining what he should do in the future to protect his agency against claims, must weigh the conduct involved by comparing it with that of a well trained water works man under like circumstances. Unless the conduct comes up to that standard, there is negligence and liability for damage claims.

A well trained water works man chooses the weight or class of pipe designed to meet the pressures and traffic loads to be anticipated. It would

probably be held by the courts to be negligence if pipe of too light a weight were used or if pressures were raised to a point beyond the safe capacity of the installed pipe. It would probably be considered negligence if pipe were installed without adequate allowance for water hammer or surge.

A well trained water works man will install pipelines with safe, adequate support and with the pipe cushioned and protected against shocks and strains. The courts have found negligence when these precautions have not been taken.

A well trained water works man will be suspicious of unexplained running water, sinking street surfaces along routes of pipelines, and other indications of possible broken mains. Failure to follow up with adequate investigations when such indications develop has been considered negligence.

When a break occurs, the well trained water works man does all in his power to mitigate damage. The courts have often absolved the water agency of liability for the break, but have held it liable for damages because of delay in shutting off the water.

A well trained water works man does all that is required of him by law or by the rules of his agency for the protection of his customers or the public. He has reason to object seriously to the imposition of duties, such as inspection of customers' premises, which he is not competent to carry out. As an illustration it is suggested that a water supply agency should have the right—by ordinance, system rule, or public utility commission rule—to shut off water service to a customer if it learns that he is employing facilities in a way to jeopardize other customers or the public system. (Evidences of dangerous water hammer or surges of a nature and frequency to indicate improper interior conditions would be an instance.) The agency should, however, resist having imposed on it responsibility for inspection of customer premises and the giving of advice. If such responsibility were imposed or assumed and not competently performed, the courts might well hold there was negligence.

Res Ipsa Loquitur Type

The law Latin phrase may be translated as "the thing speaks for itself." As was pointed out earlier, when the doctrine is called into play in a proper case, the plaintiff is held to have established an inference of negligence and to have the right to have the case submitted to the jury. There can, however, be no recovery unless negligence of the water supply agency is proved to be the proximate cause of the injury. There is no presumption of negligence but merely an inference. The courts of New York State have given more weight to the doctrine than those of any other state and, as is pointed out in the case of *Foltis* v. *New York City*, (287 N.Y. 108), have often misunderstood and misapplied it. Unfortunately, courts and lawyers in other states have been led astray by reading earlier New York cases and overlooking the fact that the Foltis decision, in effect, makes unsound much of the language in the earlier cases.

Rylands v. *Fletcher* Type

The courts of Minnesota appear to be the only ones which have adopted the doctrine of the Rylands case as applied to pipeline breaks and have held that a water supply agency must at its peril prevent breaks. In effect, this means that, in spite of the social value of water mains and of the fact that the injured party benefits from the com-

munity life made possible by the water mains, the placing and maintaining of water under pressure in the streets creates such hazards that the water supply agency must answer in damages if water escapes and causes injury, though there is no negligence.

On the facts of the Rylands case as reported, it is probable that a modern court in any of the American states would have found negligence. The English courts at the time ruled out negligence and fixed liability even though the defendant was found to be without fault. It is almost certain that the court was still thinking in the way common in early English courts, where fault was not considered essential to liability for damages. For illustration, if a man were walking and were attacked by footpads and defended himself with his cane, he would be liable for damages to an innocent person at his back, struck by the cane when it was drawn back to strike at the attackers. In such cases, the English courts have held that there was liability for damages without fault. American courts do not favor such results, and the *Rylands* v. *Fletcher* type of decision seems to be limited to Minnesota.

Seattle Case

A case now pending in the supreme court of the state of Washington is of general interest. The courts there have been in the habit of following the majority rule—negligence proof required—in passing on pipeline break cases. The water department of the city of Seattle had such a break, and properties were damaged. The cases were tried in the lower court by a judge without a jury. The judge held the city free of negligence but liable without fault. In doing so, he followed the *Rylands* v. *Fletcher* case, in spite of the precedents to the contrary in his state, and also appears to have given weight to *res ipsa loquitur*, although he had found, as a fact, that there was no negligence.

Conclusion

In trying pipeline break cases, most state courts in the United States take into account both the value of water service to the community and the rarity of breaks in relation to the exposures to risk, considering the large amount of pipe and the time element involved. Consequently, these courts hold that liability will attach only on proof of negligence. When utility personnel perform their duties as well trained water works men would, the agency will not be liable for damages due to breaks.

Cleaning and Relining Small Mains

Panel Discussion

A panel discussion presented on May 16, 1957, at the Annual Conference, Atlantic City, N.J.

Reconditioning Water Mains at Cleveland

Frank J. Schwemler

A paper presented by Frank J. Schwemler, Comr. of Water & Heat, Cleveland, Ohio.

IN the history of water system operation, a major subject for universal study has been the loss of carrying capacity in distribution and transmission mains. Since 1836, when the first scientific notice of the problem appears to have been recorded in France, many studies have been made (*1*). In 1955, Larson (*2*) was able to prepare a bibliography on the subject of carrying capacity covering 160 papers by about 260 authors. Actually, in consideration of the importance of the subject, the number of papers in Larson's bibliography is more surprising for being so low than otherwise.

Cleveland is one of the Great Lakes cities whose water supply is aggressive. Tar-coated cast-iron mains tuberculate and lose carrying capacity at about the same actual trend rate over a 30-year period as that calculated by the Committee on Pipeline Friction Coefficients of the New England Water Works Association (*3*)—that is, at the end of 30 years, mains up to 16 in. have lost up to 65 per cent of capacity, while larger mains have lost 40–50 per cent. On the small mains, the principal cause of loss is tuberculation and some after-precipitation. The larger transmission mains also show some silting. Figure 1 shows a typical condition in a main.

The practical effect of reduced main capacity is an endless series of consumer complaints, higher pumping costs, and the very real danger of severe loss by fire. Remedial measures for restoring capacity basically involve a decision between laying new mains or reconditioning the old mains. Before arriving at this decision, however, a long series of studies to determine operating requirements must be made. As these factors have been so ably presented by Avery (*4*), further expansion will not be made here. For the purpose of this paper, it is sufficient to say that if, after having been restored to close to original capacity, the main will provide adequate service, then reconditioning in place should certainly be seriously considered. Furthermore, present construction costs, particularly in congested city areas, have increased to the point where the reconditioning of old mains may be the only practical, economical decision.

The reconditioning methods today used to restore pipe capacity have been known for many years. These methods are: cleaning, cleaning and relining

with bitumen, and cleaning and relining with cement. Cleveland has used all three methods with varying results.

Cleaning Methods

There are many tools and methods for cleaning pipe. The experienced pipe-cleaning contractor generally selects the one which will prove most efficient according to the size of pipe, amount of deposit, type of deposit, and water available for use.

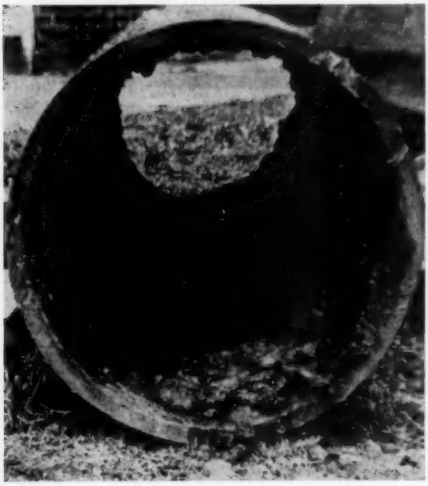

Fig. 1. Section of 16-in. Cast-Iron Main

This photograph shows a typical condition in a cast-iron main in Cleveland, Ohio, before cleaning.

After preliminary preparation, such as excavation, notification of customers, and closing branch line service line valves, the pipe is ready to be opened. An opening from 4 to 6 ft in length is made in the pipe at each end of the run. The principal pipe-cleaning contracting companies are well equipped with time-saving mechanical tools. As an example, the pipe is cut with high-speed, air-operated saws or cutters. It takes less than 30 min of actual cutting time to remove a section of 16-in. cast-iron pipe. Primarily, four different cleaning methods are used: the rotary, hydraulic, semihydraulic, and dry methods.

Rotary method. For sizes of pipe up to 12 in., the rotary method can be used. In this operation, cutting blades and knockers, mounted on helically wound springs or steel rods, are swiftly rotated against the wall of the pipe. The deposit cut from the pipe is removed from the line by water flowing against the cutting tools. Only short sections, 300–400 ft, can be cleaned between openings. Rotary cleaning is usually employed for small-diameter pipe when deposits are extremely heavy and hard. This method is also used for cleaning stub ends of water mains and fire hydrant branch lines.

Hydraulic method. The hydraulic method is usually employed when greater lengths are encountered and sufficient water is available. The length of each run can be measured in miles, depending upon the amount of deposit, the water available, the number of blowoffs and tees, the size of line valves, and other factors.

The hydraulic cleaner consists of variously shaped plows, scrapers, and brushes attached to leaf springs, which are mounted on tubular sections making up the main body of the cleaner. Metal or rubber cups of the same diameter as the pipe being cleaned are also mounted on the cleaner body. The cups, acting as piston heads, propel the cleaner forward when water pressure is applied. The springs, compressed when the cleaner is inserted into the pipe, exert a force on the plows which is sufficient to remove the deposits as the cleaner moves forward. The cleaner is so designed that a controlled amount of water bypasses the cups to

flush out ahead of the cleaner all the deposits removed from the pipe.

The hydraulic cleaner is placed in the pipe at the end next to the source of water. Because of tension on the cleaning arms, inserting the cleaner usually requires the use of hydraulic jacks, come-alongs, or other mechanical devices. At the discharge end, another section of pipe is removed and a temporary riser attached to carry the cleaning water and eventually the cleaner to street level. Mechanical couplings are used to make the connection between the pipe and the riser. After inserting the cleaner at the start of the run, the section of pipe that was removed is replaced and joined with the couplings. The speed of the cleaner is regulated by controlling the amount of water used to propel it. This can be accomplished by operating valves and pumps behind the cleaner or valves ahead of the cleaner at the discharge end.

Semihydraulic (drag) method. The semihydraulic or drag method is used where the water supply is inadequate for the hydraulic method or where the deposit is extremely heavy and hard. A semihydraulic cleaning tool is similar to a hydraulic cleaner, but without the cup sections. It is pulled through the pipe by wire rope and power winches. The wire rope is threaded through the pipe by first pushing flexible steel rods through or by using a hydraulic-cleaner cup section and water pressure to pull the rope through. While winching the drag cleaner through the pipe, a flow of water against the cleaning tool flushes the cuttings out of the pipe.

Dry method. Where water is not available in sufficient quantities or where the discharging of great amounts on the city streets and into the sewers is not possible, the dry method of cleaning can be used only for mains 24-in. or larger in size, since an operator must accompany the machine through the pipe.

The machine consists of two counter-rotating wheels approximately 12 in. less in diameter than the pipe being cleaned. Mounted on the revolving wheels are chains with cutters and brushes attached to the ends. The cleaning wheels and mechanisms are mounted on a four-wheel frame, which is powered by an air motor. The motor provides the power not only to rotate the cleaning heads but also to drive the entire cleaner. A small flow of water is maintained in the section being cleaned, sufficient to give a depth of 2–3 in. The water keeps the brushes and chain clean and also carries away the fine particles of deposit removed from the pipe.

Following the passage of the cleaning machine, all dirt and deposits not carried away by the small flow of water are scraped up by hand and hauled, in special four-wheel buggies, to the nearest access opening for disposal. Lengths of pipe up to 1,600 ft are regularly cleaned by this method, and greater lengths can be cleaned in one section, if necessary.

Results of Cleaning

The Cleveland experience with cleaning without the subsequent application of a protective lining very closely parallels the results rather widely reported in the literature. It is generally accepted that, where aggressive waters are involved, the drop in carrying capacity after cleaning will be quite sharp, owing to rapid and more extensive retuberculation of the pipe wall. One reason given for this rapid retuberculation is the removal of the original tar coating and the resultant exposure of greater areas of the machined cast-iron surface by the scraping action of the

cleaning tool. In this connection, Larson (*5*) reports:

> It was learned that the interior of all centrifugally cast pipe is partially ground for the purpose of reducing roughness prior to the application of the coal-tar coating or cement lining. In this step, most pipe interiors have been ground to the extent of 10–50 per cent of the surface.
>
> These facts indicate that tuberculation results from action of a noninhibited water on holidays, or minute holes, in those portions of the tar coating which cover the ground portions of the interior of the pipe.

It is therefore not unexpected that tuberculation will be considerably accelerated where more machined areas are exposed to aggressive and noninhibited waters.

In 1948 Cleveland contracted for the cleaning of approximately 13 miles of cast-iron transmission mains varying from 16 to 30 in. in diameter. The Hazen-Williams *C* values before and after cleaning are shown in Table 1.

Approximately 2 years after the mains were returned to service, however, the loss in capacity was far greater than would have been the case had the lines never been cleaned. The *C* of the 30-in. main had dropped to 65, that of the 24-in. main to 68, and that of the 16-in. main to 53. These losses in comparison with estimated loss in capacity according to Hazen-Williams tables and with actual trend loss as reported by Killam (*3*) are shown graphically in Fig. 2.

As a result of this experience, which so clearly demonstrated that the aggressiveness of Cleveland water would not permit satisfactory main reconditioning by cleaning alone, the city started a program of cleaning and relining in 1949. This program encompasses both distribution and transmission mains, and the relining methods used depends upon the diameter of the pipe and its location. In general, cast-iron distribution mains varying in diameter from 6 in. to 16 in. are reconditioned by the use of bituminous lining, while cement lining placed centrifugally is used for cast-iron and steel mains larger than 16 in.

TABLE 1

C Values of Water Mains Before and After Cleaning, at Cleveland, Ohio

Size of Main *in.*	Approximate Length *ft*	Year Laid	*C* Value	
			Before Cleaning	After Cleaning
30	34,200	1914–1916	86	130
24	10,000	1924	81	122
16	23,500	1914	62	121

Bituminous Lining

The bituminous process for the relining of water mains utilizes a principal of electrodeposition known and used commercially for nearly a century. Similar in many respects to electroplating, the process is based upon the phenomenon of electrophoresis.

Electrophoresis is the term used to describe the transportation of a minute particle, in a colloidal solution or in a stable suspension, under the influence of an electric field. In manufacturing

or other commercial use, the process is employed to give a dense protective coating to objects varying in size from light filaments to food containers. The objects to be coated are immersed in the colloidal suspension and act as an electrode. The use of direct current causes the particles in suspension to flow to and adhere to the electrode, or properly the anode, since the direction of migration is toward the positive pole. short space of time the anode has been covered with a dense coating, whereas the cathode is still bare.

In using the electrophoresis process, a direct current generator applies a potential difference between the two electrodes, one of which is the coating cathode and the other the pipe, or anode. The pipe is filled with the coating emulsion which is a stable aqueous suspension of water-washed

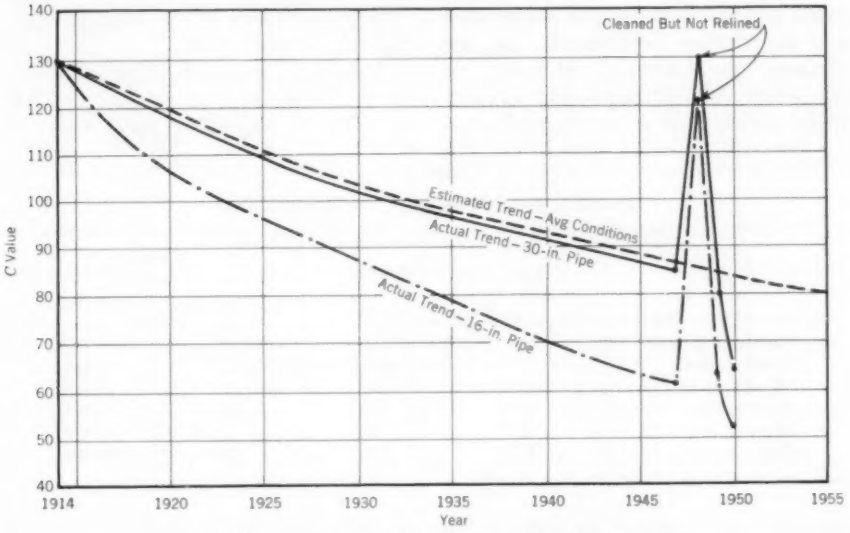

Fig. 2. Losses in Capacity Before and After Cleaning

The actual C values of 30-in. and 16-in. pipe are shown, as compared with an estimated trend under average conditions.

This is a simple description of a phenomenon whose theory is extremely complicated.

The principle of electrophoretic coating is readily demonstrated with the following experiment: Two metal electrodes are immersed in a glass vessel containing a stable emulsion or suspension of any type. Apply a direct voltage of 90–125 v for a few seconds, and then lift the electrodes from the suspension. It will be seen that in this bitumen. As the current begins to flow through the suspension, the particles of bitumen migrate toward the anode or pipe wall. Upon reaching the pipe wall, the particles adhere tenaciously and pack together forming a firm, dense layer of protective coating.

Lining Operation

Although, under favorable conditions, up to 1,000 ft can be cleaned and lined in 1 day, as is the case in all contract

operations, favorable conditions are not always present. Cleveland, therefore, requires the contractor to lay temporary service lines to all consumers connected to the main being cleaned and lined.

Through experience in working with Cleveland personnel over a period of years, the laying of temporary services and the changeover from street mains to temporary service has become very efficient. This efficiency has produced many compliments for the engineering and distribution departments. In one instance, the Cleveland Hospital, an institution of 700 beds, was satisfactorily served with more than adequate pressure and volume throughout the entire cleaning and lining operation on several long sections of 16-in. main.

Before the lining operation can be undertaken, the pipe must be thoroughly cleaned. The cleaning machine must remove all rust, tubercles, deposits, loose or deteriorated remains of original coating, and all other foreign materials from the inside of the pipe. To accomplish this, an entirely new sectional cleaning machine has been designed. Ploughs, scrapers, and wire brushes under high pressure break away deposits, dig out the pits, and brush the interior of the pipe in one operation. The design of the equipment is such that it allows on-the-job adjustments to meet varying field conditions.

For a finishing tool, a drag cleaner shaped much like a football is used. This cleaner is capable of being pulled in either direction. Therefore, two winches are used, one at either end of the section of pipe being cleaned. These winches pull the drag head back and forth until all foreign deposits and old deteriorated lining is removed. This is necessary before efficient coating can be performed.

Maximum lengths handled efficiently in the lining process range from 500 to 1,000 ft, depending upon size and construction. If cleaning is done in long sections, the pipe is subdivided into shorter lengths for lining. A swab composed of rubber disks mounted on a metal center rod is pulled through the section to remove excess water and any fine particles of deposit that might remain in the pipe from cleaning operations.

Following the swabbing operation, a wire rope and an insulated electric cable are threaded through the section. The wire rope, mounted on a power winch, is used to pull the coating electrode, while the electric cable, mounted on a separate winch and connected to the negative pole of a d-c generator,

TABLE 2

Results of Bituminous Lining at Cleveland, Ohio

Section	Size *in.*	Length *ft*	C Value	
			Before Cleaning	After Cleaning
Denison Ave.	6	341	39	112
Clayton Rd.	6	319	45	127
W. Third St.	8	310	93	113
E. 33rd St.	6	331	38	113
Urbana Rd.	6	277	44	113
Julia Ave.	6	313	56	121

carries the current to the coating electrode or cathode. The coating electrode is inserted into the pipe at the opposite end from the winch and generator, after which there is installed at the two ends of the pipe a special riser which traps and holds the lining emulsion in the main to maintain a slight head during the process.

Before the emulsion is pumped into the main, all curb stops and branch line valves are closed. During the pumping operation, care must be taken to prevent the formation of air pockets. When the main has been filled, the positive lead from the generator is attached to the pipe making it the anode. Lining starts immediately when electric current is applied to the circuit.

As the bituminous lining builds up on the pipe wall, forming an insulation, the flow of current is retarded. This is indicated by a drop in the ammeter reading on the operator's instrument panel. When the resistance to the flow of current reaches a predetermined level, the lining is completed for a distance equal to the length of the cathode. The electrode, attached to the wire-pulling rope, is then advanced its own length and stopped until the ammeter readings indicate the process is complete. This procedure is repeated until the entire section has been lined.

After removal of the cathode and pumping out of the coating emulsion, all excess bitumen is removed by a thorough flushing. The two sections removed for access to the main are then replaced, and service restored to the section. The raw lining emulsion is carefully mixed with water prior to being pumped into the main. It is necessary that a soft water be used for dilution. In cities where the total hardness of the water exceeds 86 ppm, a water softener or other chemical is used to obtain the proper degree of softness.

Results

The first bituminous lining for Cleveland was placed in 1949. That year 3,714 ft of 6-in. pipe and 2,061 ft of 8-in. pipe were cleaned and relined by the electrolytic process. The results of this work on the various sections tested by city engineering personnel are shown in Table 2.

A test period of 1 year was used to determine the continued effectiveness of the bituminous lining. During that time, tests indicated that flow capacity of the pipe was substantially the same as when first reconditioned. This determination was also substantiated by similar tests undertaken at Lima, Ohio, where the late E. E. Smith, director of utilities, reported on flow tests undertaken in February 1952, after reconditioning work in 1949–50. Results are shown in Table 3.

TABLE 3

Flow Test Results of Bituminous Lining at Lima, Ohio

Section	Size *in.*	Length *ft*	*C* Value	
			Before Cleaning	After Cleaning
High-W-Perry	20	500	69	111
North-W-Perry	10	500	60	114
Sugar-N-Wayne	12	500	85	115
Shawnee-S-Eureka	20	500	63	116

As a result of these determinations, Cleveland started a planned reconditioning program in 1952, which has been continued each year since. To date, approximately 80,000 ft of cast-iron distribution mains ranging from 6 in. to 16 in. in diameter have been reconditioned by the electrolytic method. Forty-seven per cent of the reconditioned mains have been 6 in., and 28 per cent 16 in. All mains have been located in congested areas where the cost of laying new pipe would have to be prohibitive.

Although the electrolytic process was introduced in the United States as recently as 1946, it had been in use in England for more than 25 years. However, records are available only since 1936. During this 20-year period, more than 800 miles of water mains have been lined, and sections taken from lines at random, after 10–15 years of service, reveal the pipe to be in approximately the same condition as when the lining was applied.

After the initial test program, all reconditioning work has been performed on a turnkey basis—that is, the contractor has been required not only to clean and line the pipe but also to dig excavations, to provide temporary service to all consumers by laying supplementary pipe aboveground, and to backfill and provide temporary paving. Under the contract, the city provides water and operates line valves only. The contractor must pay for street opening permits and for the cost of final repaving, although the latter work is performed by the street department and then billed to the contractor.

Under such conditions, a close and direct comparison with the cost of laying new mains can be made. The cost of reconditioning on the turnkey basis performed in Cleveland is about half the cost of laying a new tar-coated cast-iron main of the same diameter.

Cement Lining

In Cleveland, the larger water mains, 24 in. and up, are reconditioned by cleaning and cement lining. Briefly described, the procedure is as follows:

1. Prior to the application of cement mortar linings, the pipe is cleaned hydraulically or mechanically, followed by hand cleaning where necessary.

2. Access holes must be made in the pipe to permit entrance of the lining machine, materials, and personnel. The distance between openings is usually equal to a day's run of the lining machine.

3. Mortar is mixed in a special mixer located at the access hole. The mortar is delivered through a chute into a travel buggy, which transports mortar for the lining machine between the access hole and point of application.

4. A mortar supply buggy, which is attached to the lining unit, receives the mortar from the travel buggy and feeds it to the lining machine, while the travel buggy returns for another load.

5. The mortar is fed to an applicator head which revolves at about 1,000 rpm. In so doing, the mortar is thrown onto the pipe wall by centrifugal force.

6. Immediately behind the applicator head are mounted slowly revolving finishing trowels, which produce a smooth finish.

7. The thickness of the cement lining is controlled by the rate of travel of the machine. Most linings are from $\frac{3}{16}$ to $\frac{3}{8}$ in. thick.

The work performed by several cement lining contractors has been wholly satisfactory and has restored all cast-iron mains so treated to useful capacity. As cement lining, centrifugally placed,

is a generally accepted reconditioning method, further discussion is unnecessary. It is understood that experiments are being conducted, looking toward development of a practical and economical device for the application of a cement-mortar lining by the centrifugal method for distribution mains from 6 in. up to 16 in. in diameter.

Conclusion

Reconditioning cast-iron mains by cleaning, followed by the electrophoretic deposition of bitumen or by a cement lining placed centrifugally, is an economical solution to the problem of loss of carrying capacity. The electrophoretic method is used for mains up to 16 in. and cement lining for larger mains.

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Cleaning and Relining at Norfolk—*Robert W. Fitzgerald*

A paper presented by Robert W. Fitzgerald, Supt., Div. of Water Supply, Norfolk, Va.

Norfolk, Va., like many of the other older cities of the United States, has in its water distribution system many miles of unlined cast-iron water mains. The age of these mains varies from 30 to 85 years, and their carrying capacities are greatly reduced by internal tuberculation. Loss-of-head measurements indicate that the average *C* factor on these mains would not exceed 70. Some of the more severely corroded lines have shown a *C* factor as low as 40.

The solution to this problem lies in one of two methods: either the rehabilitation of the existing mains, or their eventual replacement with new mains. With these ideas in mind, the Norfolk Division of Water Supply, in 1947, experimentally cleaned and lined 1,000 ft of badly tuberculated 8-in. cast-iron pipe. This lining was applied by a process which consists of the electrolytic precipitation or plating of a bitumen coating on the inner walls of the pipe. The pipe was badly pitted on its inner walls, and the *C* factor obtained on the lined pipe was only 103. Periodic loss-of-head measurements showed that the *C* factor had been reduced to 80 in approximately 30 months, indicating that the results obtained were of a temporary nature only. Since that time other water utilities have had similar experiences.

During 1949, further experiments were conducted on water main rehabilitation. Approximately 58,000 ft of water mains were cleaned and no lining applied. This group of mains consisted of 29,000 ft of 20-in., 14,000 ft of 16-in., and 15,000 ft of 12-in. main. The average *C* factor after cleaning was approximately 115, varying from 110 to 120. Loss-of-head tests made less than 4 months after the cleaning

showed an average *C* factor of 90, with a variation from 79 to 99. The resulting reduction in carrying capacities of approximately 20 per cent within a 4-month period was, of course, caused by the extremely rapid rate of retuberculation, notwithstanding the fact that the pH of Norfolk finished water is maintained at the stabilization point for calcium carbonate solubility. This water, like many other supplies on the Atlantic seaboard, is one of low alkalinity, reasonably soft, and highly corrosive. Cleaning without the application of a protective coating was not the answer to the problem.

In 1951 and 1952, the Norfolk Division of Water Supply renovated approximately 20 miles of cast-iron water mains by cleaning and cement-mortar lining by the centrifugal process. These mains consisted of 23,000 ft of 30-in., 27,000 ft of 24-in., 27,000 ft of 20-in., 1,000 ft of 18-in., and 26,000 ft of 16-in. pipe. This was one of the pioneer cement-mortar lining contracts for 16-in. pipe using the centrifugal process. The only other 16-in. mains previously lined in this manner were at Hudson, N.Y., in 1950, and Washington, D.C., in 1951.

The 30-in. and 24-in. pipes were originally installed as transmission mains from the principal pumping station to the heart of the city. The 24-in. was installed in 1885, and the 30-in. in 1903. Since their installation, no attempt had been made to clean these mains or to restore them to their original carrying capacities until 1951. The 20-in., 18-in., and 16-in. lines were trunk mains within the distribution system. At the time that this project was carried out, all of the 20-in., 18-in., and 16-in. lines and approximately 50 per cent of the 30-in. and 24-in. lines were being used for distribution as well as transmission. Therefore, there were many individual service connections as well as side branches. In order to maintain adequate service to the customers, it was necessary to lay bypass pipelines, consisting of 4,000 ft of 4-in. and 84,000 ft of 2-in. pipe, in addition to installing numerous lateral connections. The results obtained were very gratifying. The *C* factor on these rehabilitated mains varied from 100 to 130, the average being 115. No reduction in the *C* factor has been noted since they have been put back into service.

This reconditioning process has increased the carrying capacity of these lines approximately 100 per cent. Since none of these mains shows any material outside corrosion and since the greatest age is less than 75 years, it is reasonable to believe that this restoration has extended their useful service at least 50 years. The total cost of the rehabilitation project was less than 25 per cent of the cost of replacement.

Recent Experience

During 1956, approximately 10 miles of 20-in. and 16-in. cast-iron water pipe was reclaimed by the same process used in 1951 and 1952. The contract included the cleaning and cement lining of 10,000 ft of 20-in. and 44,000 ft of 16-in. pipe. This main had originally been laid as a transmission line to serve the city of Virginia Beach. Later it had been paralleled with a 20-in. cement-lined main. The rapid growth of the city of Norfolk eastwardly, toward Virginia Beach, had caused the construction of numerous housing developments along the route of these two pipelines. This condition had eventually increased the demand for water in that area to the point where it was necessary to reclaim the old line or

replace it. The fact that the old line was paralleled with a comparatively new one made it much easier to serve the side branches while the cleaning and lining process was being carried out. In order to maintain continuous water service to the various individual services on the old line, however, it was necessary to lay 32,000 ft of 2-in. bypass. The average *C* factor on these restored mains was 130, and their carrying capacity was increased by 125 per cent. The total cost of this project was also less than 25 per cent of replacement cost.

Aside from the 1,000 ft of 8-in. pipe cleaned and lined in 1947, the Norfolk Division of Water Supply has had no actual experience in the rehabilitation of cast-iron mains smaller in diameter than 16 in. Officials are thoroughly convinced, however, that mains as small as 12-in. can now be effectively and economically cleaned and cement lined by the centrifugal process. As a matter of fact, there is now under negotiation a project for the rehabilitation of approximately 5 miles of 12-in. water main which is so badly corroded that its present *C* factor is only 40. The estimates of cost on this project indicate that this rehabilitation can be accomplished for approximately one-third of replacement cost.

It is understood that approximately 30,000 ft of water main in the distribution system of a government reservation in the Norfolk area has been reclaimed within the past 2 years by cleaning and cement-mortar lining using a mandrel. This contract included 12-in., 10-in., 8-in., and 6-in. cast-iron pipe. Apparently, the results were entirely satisfactory. The water distributed in this system is furnished by the Norfolk Division of Water Supply. Although cement-mortar lining by this process is generally more expensive than by the centrifugal process, and no actual figures on the cost of this restoration project are available, it is understood that cost would be well below that of replacement.

Since water main rehabilitation accomplished by cleaning and cement-mortar lining extends the useful life of pipe, permits better service to consumers, and actually increases the overall value of the utility plant, the expenditures therefore are considered not as maintenance or repair expenses, but rather as a capital improvement outlay and the rehabilitation is financed as such.

Installing Cement Linings at Rochester—*Lewis B. Smith*

A paper presented by Lewis B. Smith, Director, Water Bureau, Rochester, N.Y.

The first experience of the city of Rochester in installing a cement lining in pipe underground was in 1944. A 36-in. wrought-iron pipeline, which had been installed in 1873 and abandoned due to leakage in 1934, was lined in 1944 and has been in use since that time. No leakage has occurred since lining. The length of this line was 38,000 ft. The results obtained with this pipe led to the lining of two other transmission lines for an additional 280,000 ft, varying in size from 38-in. riveted steel to 24-in. cast iron.

In downtown Rochester there is a high-pressure system, separated entirely from the domestic system. This system is for fire fighting only. A

pressure of 100 psi is maintained at all times and increased to 125 psi if a fire occurs in this area.

For a number of years, this system was supplied with Genesee River water. The pipelines in the system vary in size from 6 in. to 20 in. in diameter. All of the pipelines in the system are badly tuberculated, and a considerable amount of mud and sediment is in all of the mains.

In 1954, a 5-year program was inaugurated to rehabilitate this system by cleaning and lining the pipe. In 1955, 3,100 ft of 20-in., 3,500 ft of 16-in., 900 ft of 12-in., and 300 ft of 10-in. pipe were cleaned and lined. The 20-in. and 16-in. pipe were lined with $\frac{3}{16}$ lining by the centrifugal method. The 10-in. and 12-in. lines were coated by the Tate process.

Tate Process

The Tate process consists of packing one end of the pipe to be lined with sufficient cement mortar to give a predetermined thickness of lining, depending on the length. The maximum distance is approximately 300 ft. After the mortar has been packed into one end of the pipe, a cable previously placed in the pipe is attached to a mandrel, which is drawn through the pipe, pushing the mortar ahead and against the walls of the pipe. The mandrel also pushes mortar in the connections, hydrant branches, and services, and it is therefore necessary to excavate and disconnect all services and hydrant branches from the mains. This, of course, raises the cost and also interrupts traffic, which today has to be considered on all work in heavily traveled streets.

This process for applying a cement lining to the interior of pipelines was developed in Australia and was first used in Sydney in 1930. The process was first brought to the United States in 1939, and since that time has been used here in the rehabilitation of approximately 3,000,000 ft of cast-iron and steel pipe, ranging in sizes from 4 to 16 in. The process had been generally accepted as the best permanent solution for maintaining carrying capacity in small pipelines by protecting these lines from tuberculation. A number of Hazen-Williams flow coefficients were determined on pipelines lined with the Tate process. The coefficients, based on the actual size of the lined pipe or on the reduced area, demonstrated that a very smooth surface was obtainable using this process. These Hazen-Williams coefficients ranged between 120 and 145. When these coefficients were calculated on the nominal rather than the reduced size of the pipe, they ranged from 90 to 115. This difference was, of course, due to the reduction in cross-section area of the waterway with the thicker lining. The thickness of a Tate lining was determined by the process, and ranged from $\frac{3}{16}$ to $\frac{5}{16}$ in.

Centrifugal Process

In the last few years, a modification of an existing process for cement lining by using centrifugal force to apply a premixed mortar was adapted to small pipelines. The principle of application is the same as for large pipe, but, because of the problems in working in small pipelines, much of the equipment bears little resemblance to the machine for larger pipe. The basic difference between lining large and small pipe with the centrifugal method is that, in the larger pipelines, the final finish of the lining depends on paddle type trowels, whereas in the smaller sizes, the finish depends on a much

closer control of machine and materials, as there is no troweling done. With the new centrifugal machine for small pipe, the cross-sectional area can be controlled by controlling the lining thickness in very much the same way as in the larger sizes. Approximately 35,000 ft of pipe have been lined using this type of machine in small pipe, and the few tests that have been run to determine the flow coefficients indicate that a coefficient of approximately 120 may be expected on the actual diameter. This range is somewhat lower than the coefficients obtained on the actual diameter of a Tate lining, because the surface is not as smooth as a Tate surface. It is interesting to observe, however, that the coefficient based on nominal diameter ranges between 90 and 110. This is in the same range as was found in the Tate coefficients on nominal sizes. The answer to this correlation is that the thickness of the centrifugally applied lining can be controlled, and is considerably thinner than that applied in the Tate process. A lining thickness of $\frac{1}{8}$ in. is placed on cast-iron pipe and on steel pipe where no extreme problem of exterior corrosion is encountered. Should the desirability of an extra thickness of lining outweigh the greater reduction in cross-sectional area, the lining thickness may be increased.

The primary reason for the development of the centrifugal process for small pipe was to eliminate the necessity for excavation at laterals and corporation cocks. The Tate process was successful in lining transmission mains, but required an excavation at each lateral or tap in order to prevent the mortar from being forced up into the lateral connection. This has proved unnecessary with the centrifugal machine. Openings in straight pipe may be 500 or more ft apart when using the centrifugal machine. Therefore, the total number of excavations using the new process is considerably less, and the process should prove to be more economical.

In 1956, it was decided to clean and line approximately 17,000 ft of 12-in. pipe in the high-pressure system. At first, it was decided to use the Tate method, but upon learning that a test section of steel pipe 481 ft in length was to be lined by the centrifugal method, it was decided to wait until the results of this experiment were available. This pipe, which had an inside diameter of $7\frac{3}{4}$ in., was tested before it was lined and again after the lining was completed.

For the test made before lining, the average Hazen-Williams coefficient was found to be 128, based on the calipered diameter of $7\frac{3}{4}$ in. Seven days after cement lining had been applied, the average coefficient was 122, based on the average inside diameter of $7\frac{1}{4}$ in. The Hazen-Williams coefficient of the original diameter of $7\frac{3}{4}$ in. was 103.

When the above results were received, it was decided to use the centrifugal method in lining the 17,000 ft of 12-in. main. This would give practically the same results as the Tate process and would be less costly, as it would require openings only about each 500 ft, and it would not be necessary to disconnect service and hydrant connections or gate valves.

The gate valves in the line were operated several times shortly after the lining was applied. All of the services were flushed out after the work had been completed, and no plugging was encountered. The spray from the centrifugal machine throws some mortar into the services, but does not leave a plug. The loss of head was measured

after the line was completed; a coefficient of 104 based on the nominal original diameter was obtained.

Fire Requirements

There are two basic reasons for increasing the capacity of small pipelines. The first is that of increasing transmission lines. The second, and probably more important, is that of meeting fire flow requirements in small and large cities. Fire flow requirements are constant. It is difficult to juggle a system to provide temporary quantities and pressures for fire needs in the same manner as is often done to provide temporary relief for peak demands in the summertime. The cost and inconvenience of replacement of small mains in high fire flow requirement areas is almost prohibitive. The number of other utilities already in the street requires the use of a tremendous amount of hand labor in excavation and in handling pipe and this, combined with creating hazardous traffic conditions, has kept many cities from providing the necessary reinforcements to their old distribution grids. The cost and inconvenience of repeated cleaning in a heavily populated distribution system makes this method of temporary relief undesirable.

When fire requirements are considered, the condition of the main is as important as the size of the pipe. A 12-in. line with a coefficient of 40 is only equal to an 8-in. main with a coefficient of 120. An 8-in. main with a coefficient of 55 is only equal in capacity to a 6-in. main with a coefficient of 120. Carrying this relationship further, if a 4-in. main is insufficient for fire protection, then so is a 6-in. main when its coefficient has fallen to 40. Before it reaches 40, steps should be taken to remedy this situation. When a water works superintendent looks at his distribution map and is pleased and satisfied that it appears strong because of a preponderance of 8-in. mains, he should remember that if the coefficient of these mains is below 60, he must consider them as 6-in. mains until he does something about the interior of the pipelines. In this light, some apparently strong systems prove to be much weaker than they appeared at first glance.

The total capacity of a pipeline is very important in evaluating the rehabilitation of an existing main. Of perhaps even greater importance is the assurance that the improvement will be permanent and that new design incorporated with rehabilitation can depend on the future carrying capacities of the existing lines. No one today under ordinary circumstances would install new pipelines that were subject to tuberculation and reduction of carrying capacity. This holds true with materials used in cleaning and lining.

In rehabilitation of small pipelines, it is not uncommon to double or even triple the existing carrying capacity of the main.

Application of Electronics to the Water Supply Industry

Howard Jacoby

A paper presented on Mar. 22, 1957, at the Illinois Section Meeting, Chicago, Ill., by Howard Jacoby, Assoc. Editor, Engineering News-Record, New York City.

THIS article attempts to cover the gamut of existing applications of electronics in water supply and provide a look into the future; a description of the electronic mechanisms themselves, however, will be left to the electronic engineers. The author's interests and, it is felt, those of the water supply practitioner are not primarily in the intricacies of the devices but, rather, in their potentialities and cost.

Today, and in the years to come, those in the water supply field face an extraordinary challenge. By and large, in years past, domestic and industrial water supplies have been planned and built independent of other uses of water and the agencies involved in potable water supply have been rather localized.

This approach has, in most instances, been adequate up to now. But the signs grow clearer every day that domestic and industrial supply schemes will have to be prosecuted on an ever widening geographical basis, and, sometimes, in intimate association with combinations of flood control, navigation, irrigation, hydroelectric power, and pollution abatement uses of water.

Where water supply once would have been only the bump on the log of multipurpose resource development, today there is an inescapable indication that water supply will be a more controlling —indeed, in many instances, *the* controlling—facet of such projects.

This conclusion—and it is shared by many—bespeaks fundamental changes in carrying out water resource construction schemes. The federal government is now the dominant influence, although water supply development has traditionally been reserved to local agencies. It appears now that large agencies will be required to tackle the water projects of the near future. Some form of partnership between local agencies, states, and the federal government is the prospect.

The exact form which such organization will take is a complex problem, and not within the scope of this article—although the implications of the impending changes are. For, regardless of the final organization, the existing suppliers of water are going to have much more responsibility for the nation's water resources development.

These new responsibilities will encompass new planning concepts, more complex economic decisions, operation of broader transmission and distribution systems, and, perhaps, the design and operation of radically different treatment plants wherein two or more qualities of finished water are produced for potable and industrial needs. To carry out these responsibilities, new tools and methods for quicker and more

searching analysis and for better operational control will be required. The field of electronics should provide some of these.

Electronics is commonly defined as the field dealing with the control of electrons in electrical flow, especially by the use of vacuum tubes, transistors, and photoelectric cells. An electronic device is merely an electrical device incorporating some sort of control over the flow of electrons. Generally, electronics deals with small amperages.

For convenience, the applications of electronics in water supply have been divided into three categories: telecommunication, electronic computers, and, miscellaneous.

Telecommunication Applications

Telecommunication—involving radio, television, and telemetering—embraces the leading uses of electronics at present.

The many applications of two-way radio communication are now so common that water officials often wonder how they ever got along without it in communication between offices and field maintenance crews. An outstanding example of its application is found in Atlanta where the radio dispatcher has full view of the distribution system from a galaxy of meters mounted before him.

An interesting prospective use of radio in water plants is a system involving induction radio for communication with persons in noisy places such as pump stations—particularly the steam-driven variety. Common radio is called space radio, since the waves are transmitter over relatively long distances. In induction radio, the magnetic field which emanates from a current-carrying electrical conductor is utilized. Voltage variations in the conductor produce corresponding variations in the magnetic field which are detected by the receiving apparatus. It is a relatively simple matter to string wire or other conductors throughout a noisy interior area, with the result that personnel carrying small receiving sets can be contacted at any time—even when standing next to the noisiest of steam turbines. A small transmitter which enables two-way communication can also be provided to desired personnel, although at somewhat higher cost —at this time—than the one-way communication.

As far as is known, there is no such induction radio installation in the water field, but one has recently been completed for an industrial pump room and power plant.

Closed-circuit television has been introduced in the water supply field, although in a very limited manner. Applications include guarding plant entrances, checking reservoir levels, reading water gages; underwater study of potential dam sites, oyster beds, and such areas; checking burner flames and smokestacks at boiler installations, and a number of uses by contractors in guiding cranes and shovels, placing concrete, and general viewing of large construction sites.

For older treatment plants, with groups of meters scattered in a number of buildings, closed-circuit television may offer a cheaper means of centralizing control than moving or duplicating the meters. Those in the sewage treatment field probably would find television more useful in this connection.

Telemetering and supervisory control of remote equipment is a very active field for electronics, and one in which water supply people have taken the lead. Although many telemetering or remote-reading systems transmit information via hydraulic, pneumatic, mechanical, and electrical means, the more advanced installations are turning to

electronic circuitry, often over leased telephone wires. The latest method of transmission, employed in Warren, Ohio, is microwave radio which eliminates all physical installations between remote and central points.

Today's applications of telemetering are generally confined to reporting reservoir level, water pressure, and quantity of flow information. Uses for the future include transmission of accounting information, burglar alarms, and feeding of inventory control information.

A survey of many water agencies taken by *Engineering News-Record* in 1956 (*1*) indicated that nearly every water agency either already employs some form of telemetering or is seriously considering such installation. The survey indicated that the majority of existing and planned installations are advanced to the stage of using telemetering for the reporting of information. A goodly number of systems carry to the next logical step—remote supervisory control over such aspects as pump and valve operation.

Electronic circuitry of the leased-wire or microwave varieties for transmission of telemetered information generally proves simpler and cheaper than the other types.

Use in Measurement

Electronic means have been used to measure liquid levels in petroleum refineries and chemical plants, and these can be adapted for use in the water supply field. A combined transmitter-receiver at the bottom of a tank of liquid directs sound pulses to the liquid surface where they are reflected. Round-trip intervals are measured and the data are converted into decimal readings. The information can be transmitted over long distances.

Another electronic method for measuring liquid levels consists of placing a small quantity of radioactive material in a float and mounting radiation detection equipment alongside the tank. The detection equipment which incorporates electronic circuitry can thus determine levels of the liquid at any given time.

Electronic scales have a very promising future in performing the various weighing functions required in treatment plants. Such a scale incorporates a number of load cells, each of which consists basically of a short steel column which compresses under load, a strain gage to measure the compression, and electronic mechanisms which translate strain gage indications into electrical signals and, in turn, to weight readings.

Information from the load cells can be transmitted to electronic output devices such as total and net weight computers, automatic printers, remote dials, signaling units, and visual indicators. This accessory equipment is also applicable to conventional lever-type scales.

In comparing electronic and lever scales, the electronic, or load cell, scale is found easier to service routinely, maintains accuracy longer, and wears better, but is more difficult to repair because of parts procurement, and has higher initial and repair costs.

At present, electronic scales are being promoted for truck weighing, particularly in the highway field. But they are quite applicable in the water field. It seems likely that electronic scales will be adopted to some degree for the smaller scales that are part of chemical feed equipment. Even more likely, in treatment plants, is an electronic mechanism linking the residual chlorine recorder with the chlorine feeder, for automatic maintenance of a constant residual, regardless of variations in flow or quality of water.

A specialized gas detector (*2*) made for the US Army has had application in

the water field. In the device, a chemically impregnated paper tape moves past one photoelectric cell, is exposed to the air stream being tested, and then moves past a second photoelectric cell. Any gas in the air discolors the tape and unbalances current flow in the cell, which, in turn, trips an alarm.

Electronics has also been applied to materials handling. A number of US Air Force supply depots employ a magnetic-tape-controlled conveyor system that automatically delivers packages onto any of twenty or more branch conveyors in a warehouse (*3*). An endless magnetic tape represents the main conveyor. Movement of the packages on the conveyor is electronically timed on the magnetic tape so that when a package is opposite the branch conveyor leading into the chosen area, a pneumatic pusher sweeps the package onto the branch conveyor.

Chicago's application of the electron microscope, instrumental in reducing the time required for coliform bacteria tests from 72 hr to approximately 16 hr. should also be noted.

Computers

Though at present overshadowed by radio and telemetering, electronic computers will, it is believed, become of all electronic tools the most useful to water supply agencies—both large and small. There are two types of electronic computers: analog and digital. The analog computer employs voltages to represent physical quantities, much as the common slide rule represents logarithms of numbers by length. The McIlroy fluid network analyzer (*4*) such as that used at Baltimore and Philadelphia to analyze water distribution systems is an analog computer, although it is electrical, not electronic, and is a highly specialized machine. Its operation, however, is like that of an electronic analog computer.

The analyzer employs electrical resistors whose resistance varies with current (to simulate the hydraulic characteristics of water flowing in a pipe). Voltage-drops through individual resistors indicate head loss, and the current indicates the volume of water flowing. When a network is duplicated on the analyzer, voltages are impressed and the system is analyzed instantaneously. Different system demand conditions are obtained by the flick of a knob. Changes in the pipelines, however, require stopping the machine to change resistances.

In a general-purpose electronic analog computer, this relatively simple arrangement is replaced by much more complicated electronic circuitry which enables a wider range of variables to be introduced instantaneously, and also enables the machine to solve a wider range of problems. The basic function of an analog computer remains the same as that of the analyzer, however; it handles constantly varying quantities for a given set of conditions (either built into the machine or set up for a particular problem) and produces answers in the form of either a steady voltage or a plot of voltage varying with time—which is the more common form.

In contrast, the electronic digital computer works with actual numbers, much as we compute problems manually. The essence of digital computers is that they work thousands and even millions of times faster than humans (and also desk calculators), and can perform operations continuously and automatically when given a set of instructions (called a program) by which to operate. They do not get bored and make but a minute fraction of the mis-

takes common to humans. But they are not brains; they do not exercise judgment, and, given unrealistic data, they will turn out unrealistic answers.

Computer Programs

Computer programs are basically a step-by-step breakdown of a problem into the basic functions of addition, subtraction, multiplication, and division, plus, if need be, a request here and there for the computer to compare two numbers as to sign or relative quantity.

To illustrate a digital computer program, assume a group of consecutively numbered boxes in a post office and a diligent clerk who follows instructions without deviation. The clerk is directed to receive his first instruction from Box 1 and to take each succeeding instruction from the next box in order, unless told otherwise.

Box 1 might carry the instruction, "Copy on a piece of paper the number in Box 55"; Box 2, "Copy on the same piece of paper the number contained in Box 56, add the two numbers and write the total"; Box 3, "Copy the total on another piece of paper, place it in Box 57, and destroy the piece of paper previously contained in that box."

From the foregoing, it is seen that if problems of an essentially arithmetic nature are posed, the digital computer is called for. But if continuously variable quantities are to be dealt with, as is the case in dynamic systems, the analog machine can be more suitable.

When one reads these days about a gigantic electronic computer that has achieved some wondrous computation, it is likely to be a digital computer. This type, much newer than the analog computer, first achieved fame during and after World War II by performing elaborate scientific calculations. Then came the manufacturers who saw digital computers as ideal for replacing clerks performing highly repetitive commercial work. Finally, in the last several years, digital computers have been applied to repetitive-type engineering calculations. The highway field in particular has embraced them at a dizzying pace in just the last 12 months. At last count, 26 states will soon have them at engineering work. In the meantime, analog computers are still around and doing a thriving, but unpublicized, business.

Electronic computers are already being employed in the water supply field, but almost exclusively in commercial applications. The Los Angeles Department of Water and Power, for example, makes up an 11,000 man payroll on a digital computer. Chicago and many other cities do the same. Other standard commercial applications of digital computers include cost accounting, general accounting, handling of statistics, inventory control, and invoice preparation.

Computer Network Analysis

Of the engineering applications in water supply, far and away the most important is distribution network analysis. Several programs for this analysis—which are based on the Hardy Cross method—have been written for a digital computer. Sufficient experience has not yet been gained to permit accurate assessment of benefits in terms of faster and cheaper computation and, most important, better answers. But using a rather unrefined program on a prototype computer, one user—a Miami consulting engineering firm—has given the author these figures: For 20 different arrangements of a ten-loop network, the computer took 27 hr of machine time, compared to an estimated 4 man-months using normal methods.

Preparation time for the program, which can be used over and over again, took a surprisingly short 3 weeks. Most programs for civil engineering problems require a number of months to prepare and to search out deficiencies.

Recently, an integrated electronic computer data reduction and processing firm was formed. This company * has completed a computer program for pipeline network analysis. Charges are $0.42 per loop per iteration, based on the Hardy Cross method. The user supplies, on a printed form, his estimates of quantity and direction of Q and K factors for each length of pipe. Answers are returned within several hours to a day or two in a tabulated report which shows direction and quantity of flow and the amount of head loss in each line.

It seems clear that computer benefits on the distribution system problem will be of the same magnitude as that achieved with the McIlroy network analyzer. Philadelphia water commissioner Samuel S. Baxter recently informed the author that the analyzer is saving 90 per cent of design time, and that reconstruction cost of a distribution system serving a 50,000-person area had been reduced by $300,000 with the analyzer. Incidentally, this machine cost approximately $40,000.

Other Applications

Although the analyzer is a single-purpose machine, the electronic computer, particularly the digital type, offers relatively great flexibility. Other engineering applications pertinent to the water supply field that have been programed on digital computers include: liquid level calculation, ditch and culvert design, extension and analysis of bids on construction projects, preparation of statistical construction reports, solution of all types of simultaneous equations, computation of optimum river regulation schedules for a multipurpose multiproject river development, analysis of rigid frame structures, and a host of other structural engineering problems. Analog computers have effectively calculated flood routing, surges in sewers, and air venting in pressure water lines.

Actually, digital computers can be programed for almost every normal engineering calculation. They will not be, of course, because many problems do not occur frequently enough, and others are performed faster by normal methods (considering just the physical movement to and from the computer).

How computers will be employed in the water supply field is a difficult question to answer at this time. It will depend on the size of the user's organization, its breadth of responsibility, and whether it can combine commercial and engineering applications of the computer. The prediction is ventured, however, that even the smallest water agencies will become computer users, if only to rent machine time at a large data processing center. These centers, incidentally, are maintained by most manufacturers, many universities and research agencies, and a growing number of private entrepeneurs. Another possibility is for a number of smaller organizations to combine to rent a computer. Renting is almost universal practice today, because the machines become obsolete very quickly.

Cost

Of the three types of machines mentioned, the network analyzer and the analog and digital computers, the digital computer will, it seems, find broadest

* Datics Corporation, Ft. Worth, Tex.

application in the water field. It can do almost anything the others can and a greal deal more—though sometimes not as fast. Smaller machines of this type rent for about $1,000 a month. Medium-size machines, such as employed by the Los Angeles Department of Water and Power, rent for around $6,000 a month, which includes a necessary amount of accessory equipment.

Fortunately, there is a fairly inexpensive method of becoming a computer user. There is general agreement among existing users that the best approach is to pick one or two bright engineers, preferably with a good deal of experience, and send them to one of the programing schools run by all manufacturers and by several universities. In a surprisingly short time, one can get a good idea of whether and how the organization's problems are suitable to solution by computers. It is the members of the organization, not the computer experts, who are best able to plan the program.

The process does become somewhat expensive once the decision to go ahead with computer work is taken. Preparation of programs, computer rental, and computer operating personnel split the total cost roughly into thirds. The gap between the initial decision and smooth production of practical answers cannot be bridged simply by waving a magic wand. The trip is expensive and often lengthy. The rewards are great, but so is the effort required to achieve them.

It is hoped that this recitation of the many applications of electronics in water supply will stimulate the reader's imagination. There seems no limit to application of the concept.

For example, an enterprising city in Pennsylvania, bothered by the presence of too many starlings, made a magnetic tape recording of a captured starling being held by its legs. The recording was played from a sound truck that toured the city for several nights. Success was achieved: while the other feathered species remained unaffected, all the starlings were frightened off. Thus, even so classic a problem as the sea gull roosting in reservoirs may be susceptible to solution through electronics.

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Discussion

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In referring to the water supply industry's increasingly complex planning situations, the author has touched on a very important point—one relevant not only to his discussion of electronic applications but to other areas as well. In pointing out that old barriers are being broken and that new approaches will be possible, he is, in effect, calling on his readers to reexamine basic concepts; surely nothing could be more fruitful or, it would seem, absorbing.

Most of the applications referred to are offshoots of the avalanche of new developments which has been revolu-

tionizing electrical engineering for about 20 years. This avalanche, which resulted from exactly the kind of thinking which the water supply field now must face, is not just a matter of new engineering materials, components, and equipment. New mathematical tools are in use—newly discovered ones like information theory; old techniques newly applied, as in the use of Laplace transformations in design of closed-loop control systems and the application of symbolic logic to computer design. Most rewarding is the fact that barriers to cooperation with other specializations have been broken through. Now, electrical engineers, mechanical engineers, chemical engineers, chemists, civil engineers, physicists, experimental psychologists, and mathematicians join forces to deal with problem situations. It is this expanding area of cooperative action which gives the developing techniques of electronics power, scope, and significance, just as the expanding area of concern of water supply practitioners produces expanded interests and responsibilities.

If the water supply industry looks at its problems in this same spirit, there is every probability that it will find powerful allies in electronics and related specializations. If this occurs, there is no visible limit to the possibilities.

Specific Points

On more specific points, and following the author's outline, it would seem first, that in a discussion of telecommunications, automatic logging typewriter systems surely deserve inclusion. These produce typewritten sheets showing periodic values of process variables—pressure, flow, temperature, state of equipment, and so on. They can operate on telemetered data, of course, and can be set to record upon demand by the operator and upon occurrence of an alarm condition, as well as on a regular schedule. Some of their first applications have been in oil refineries where installations costing between $5,000 and $50,000 have been announced, including one which records 480 variables. There are many situations where such tabulations of data are preferable to chart recorders. Such systems also offer the possibility of producing operating data in automatic-handling form—punched tape like a teletype's, for example—which could be fed into a computer or a punched-card accounting machine installation to produce summaries of consumption, withdrawals from wells, pressure averages and deviations, and others.

Another development worthy of inclusion is the graphic panel control board. This technique, also much used in chemical process plants, combines instruments with a diagram of the process so that readings are found close to the point in the process diagram to which they refer. The train location indicating boards of railroad "centralized traffic control" systems are a related development. The present state of the technique by no means represents the fullest development of the underlying idea, which appears to the writer to be that the design and arrangement of indicators should be determined by their contributions to the operator's convenience and ease in grasping information, and not by case design meant to protect instruments from rough treatment.

In the application of supervisory (remote) control and telemetering equipment the author says that ". . . water

supply people have taken the lead." Certainly they have installed much such equipment, and perhaps their influence has brought some of it into existence, but other fields should be considered. The Long Island Lighting Company, for example, spent $6,000,000 on a new central operating headquarters, including the system operating room where the company's generation, interchange, and distribution of gas and electricity is controlled. The Southern Company Power Pool controls from a power coordination office 30 major plants, both steam and hydroelectric, spread over 100,000 sq miles in four states, through telecommunications facilities and a computer. The latter, a special-purpose analog device, although it weighs 1,800 lb, has only eight electron tubes and two electromechanical servos. It is a relatively simple computer, but it is saving the company more than $200,000 per year.

The Southern Company Power Pool is one of the country's really big operating entities. The Long Island Lighting Company is, perhaps, just outside the list of the country's 30 largest power producers. Neither is typical, but the kinds of projects they have carried out are widespread in the electric power industry. Larger organizations have even more elaborate programs. An AIEE committee in 1953 surveyed 119 operating companies in the United States; 77 respondents reported that, of their 12,564 substations, 65 per cent were unattended—that is, under automatic control or control by telecommunication from remote spots.

Remote control and telemetering applications have flourished in other environments. Oil pipeline operating companies span hundreds of miles with telecommunication control. Radio broadcasting stations are controlled remotely from the studios. There are the process plant control systems and railroad centralized traffic controls, previously mentioned. The military radar air-warning and antiaircraft control systems, of which the Air Defense Command SAGE effort is in many ways the most elaborate, are very much more complex. The water supply field appears to be just beginning to exploit the telecommunications techniques it has been using.

The author points out, correctly, of course, that closed-circuit television is an electronic tool with many applications in water supply work. In order to ". . . offer a cheaper means of centralizing . . ." meter-reading and control, however, it would require the existence of special circumstances. A line of equipment of this sort has recently been announced by a manufacturer *; a minimum arrangement will cost $2,000, including installation.

Infrared communications links may deserve mention in connection with the future of water supply telecommunications. The ranges possible with such equipment in bad weather are short by comparison to radio, for example, but they may well be long enough for a considerable part of the remote control and telemetering requirements of water supply organizations. Infrared offers the advantages of radio without such difficulties as FCC channel allocations.

With respect to the application of electronic computers to water supply work, only one point supplementary to the author's discussion suggests itself. The use of computers as "on-line" ele-

* Allen B. Du Mont Laboratories, Passaic, N.J.

ments of the control system of a water supply organization is within the area of practicability and will become even more so. Mention has been made of the use of computers in electric power network control and of the SAGE air defense system which is designed, to a large extent, around a digital computer. Analyses have been made of the application of computers to control of oil refineries. Theoretical work done by mathematicians provides a basis for such studies. Economic justification, of course, is a matter of individual situations—but the potentialities are real.

One addition to the suggested program for becoming a computer user may bear mention. The engineers assigned to the project might profit by some discussion with an applied mathematician. Many problems which look formidable by the usual standards have turned out to be quite tame when attacked by a specialist in approximations.

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Urban Water Requirements in California

Max Bookman

A paper presented on Apr. 26, 1957, at the California Section Meeting, Santa Monica, Calif., by Max Bookman, Dist. Engr., California Dept. of Water Resources, Sacramento, Calif.

THE unprecedented growth of California's cities has resulted in an expanding demand for water. Comprehensive long-range planning and construction of water supply projects by responsible public and private water agencies are required to cope successfully with these demands. The preparation of such plans, however, requires the projection of water requirements far into the future. Some assistance in this connection may be found by noting certain trends indicated in recent investigations made by the State Department of Water Resources.

Population Growth

In the 1930–1950 period, the population of California practically doubled, reaching a total of 10,500,000 people. Since the 1950 census, the rate of growth has increased, and today the total population approaches 14,000,000 people. California is now the second largest populated state in the United States, and may become the largest populated state before 1970. A number of forecasts estimate the population of California in 1970 will be 20,000,000, and for planning purposes the State Department of Water Resources has estimated the population of the state may someday total 42,000,000 persons. These estimated figures forewarn that the impressive growth already experienced is only a beginning, and there is every reason to believe that the population may triple in the distant future.

Population Centers

Examination of the pattern of present urban development shows the large population centers to be located principally along the coast, with smaller urban areas located in the interior. Urban areas, however, occupy only 1 per cent of the state's total area. It is interesting to note that within the three great metropolitan areas—San Francisco, Los Angeles, and San Diego—approximately two-thirds of the state's population is located. These three metropolitan areas are placed in areas of limited water supplies, and are already largely dependent on imported water to meet their needs. The imported water supplies have been made possible by the construction of monumental engineering works.

In the San Francisco Bay area, water has been imported through three principal aqueducts—the Hetch-Hetchy Aqueduct of the city of San Francisco, the East Bay Aqueduct of the East Bay Municipal Utility District, and the Contra Costa Canal to the Contra Costa County Water District. The Mokelumne River Aqueduct, first put into operation in 1929, imports water from the Sierra Nevada to the Oakland-East Bay Area, a distance of more than 100 miles. The city of San Francisco

obtains its imported water supply through the Hetch-Hetchy Aqueduct which first delivered water in 1936, and which also has its source in the Sierra Nevada Mountains, 160 miles away. The Contra Costa Canal is a unit of the Central Valley Project and delivers water from the Sacramento-San Joaquin Delta to Contra Costa County, a distance of 48 miles.

In the Los Angeles metropolitan area, water is presently imported through two aqueducts—the Los Angeles Aqueduct and the Colorado River Aqueduct. The Los Angeles Aqueduct, which imports water for the city of Los Angeles from the Mono-Owens valleys, a distance of more than 257 miles, was first put into operation in 1913. The second source of imported water to the Los Angeles metropolitan area is through the Colorado River Aqueduct of the Metropolitan Water District of Southern California. This aqueduct, which was completed in 1941, transports water from the Colorado River, a distance of 242 miles, to serve not only the Los Angeles metropolitan area, but also the coastal areas of Southern California from Los Angeles County to San Diego County.

The San Diego metropolitan area is served by a branch of the Colorado River Aqueduct called the San Diego Aqueduct. Imported Colorado River water was first delivered to San Diego County in 1947 through the 70-mile aqueduct which extends from the junction of the Colorado River Aqueduct at San Jacinto in Riverside County southward to terminal storage at the San Vicente Reservoir in San Diego County.

State Urban Requirements

Estimates of present urban water requirements in California, as well as similar requirements under conditions of ultimate development, were made by the State Department of Water Resources in connection with the preparation of the California Water Plan (*1*). This survey found that the urban water requirements for the year 1950 within the state amounted to approximately 1,700,000 acre-ft a year, and that under ultimate conditions of development the water requirement would increase to an annual amount of 7,800,000 acre-ft, or approximately 4.5 times the present urban water requirements.

TABLE 1

Unit Values of Annual Water Requirement in Los Angeles Metropolitan Area

Land Use Classification	Depth of Water Per Unit Area—*ft*		
	Delivered		Consumed Use of Applied Water
	Present	Ultimate	
Residential			
Single	2.6	2.8	1.3
Multiple	4.5	5.0	0.3
Estate	2.0	2.2	1.5
Rural	1.8	1.8	0.8
Commercial			
Outlying	3.4	4.0	0.4
Downtown	10.2	11.0	1.1
Industrial			
Manufacturing	9.2	8.5	1.4
Schools	0.9	1.1	0.4
Irrigated Crops	1.7	1.8	1.5

Unit Uses of Water

In connection with the studies for the California Water Plan, special investigations were made of unit uses of water within metropolitan areas. Unit uses were estimated by means of a sampling procedure in which an inventory

was made of the measured water deliveries to sample areas representative of each category of land use. With residential and commercial areas, for example, single blocks devoted to such land use were chosen as sample areas; in industrial areas larger samples were chosen because of the greater range of unit values of water use. The unit values thus derived for the coastal area of Los Angeles County are presented in Table 1.

The average use of water in residential areas is not much different from irrigation requirements for the same areas. Industrial and commercial delivery requirements, however, are four to five times that of an equal area devoted to residential or average agricultural requirements. Increase in industrial development thus imposes heavier demands on water supplies. Industrial development and, usually, concentrated residential areas, furthermore, require the installation of sewage systems for disposal of wastes, and in the coastal metropolitan areas these wastes are disposed to the ocean. This increases the urban water requirement substantially over that in unsewered areas since the opportunity for reuse of the unconsumed portion of the applied water is lost.

Metropolitan Requirements

By applying the unit values of water requirements to the surveyed areas of various classes of land use, the present seasonal water requirements for the metropolitan areas were computed (*1*). Similar estimates were made for these same areas under conditions of full development. The water requirements for each of the three metropolitan areas, as of 1950, are shown in Fig. 1.

In the San Francisco metropolitan area, the present water requirements are estimated to be approximately 725,000 acre-ft per year, and 3,125,000 acre-ft annually will eventually be required for full development. The present requirements are being met by approximately equal amounts of local and imported supplies, and the entire available imported supply is not yet fully utilized.

In the Los Angeles metropolitan area, the present water requirements total approximately 1,130,000 acre-ft per year and, under conditions of full development, will require a supply of 2,670,000 acre-ft annually, or about twice the amount of water being used at the present time. The present water demands are being met by local and imported supplies, but not in sufficient amounts to equal the present use, so that an overdraft on the local supplies, estimated to be 266,000 acre-ft per year, has resulted. Additional imported supplies of Colorado River water are available to meet the deficiency.

In the San Diego metropolitan area, the present requirements are approximately 130,000 acre-ft a year, as compared to an ultimate demand of 470,000 acre-ft. The present demand is supplied by about equal amounts of local and imported water; whereas the ultimate supplemental water requirement is more than three times the present available supply. The present critical water shortage in San Diego County is a result of the fact that local supplies were not utilized on a safe yield plan of operation.

Los Angeles Area

The more extensive studies made in the Los Angeles metropolitan area on water requirements supply interesting information regarding the proportionate share of water required for various

classes of use and the effect of urban encroachment on previously irrigated areas. The studies, partly summarized in Fig. 2, show that under present conditions of development, the total daily use is 1 bil gal. Residential use accounts for approximately 40 per cent, and irrigation use, 37 per cent. Although, as previously mentioned, industrial use has a much larger unit requirement, the present industrial use is estimated to be approximately 170 mgd, or 17 per cent of the total use. Under ultimate conditions, it is estimated that the Los Angeles metropolitan area will require approximately 2.4 bgd, or 2.4 times the amount of water being used at the present time. Water required for residential use is expected to increase from the present 40 per cent to 60 per cent of the total requirement, and irrigation use is expected to decrease from 37 per cent to 4 per cent. Industrial use of water is expected to increase from the present 17 per cent to 24 per cent. It may therefore be seen that, even under ultimate conditions in the Los Angeles metropolitan area, residential water requirements will far exceed water required for all other purposes.

In all three of the metropolitan areas being discussed, much of the expanding urban development is taking place at the expense of land under irrigational use. The effect of this change in land use on water requirements was evaluated in a detailed study of land and water use in Los Angeles County. The investigation, which evaluated the changes between 1950 and 1955 (*2*), found that during the 5-year period, the population increased from 4,122,000 to 5,034,000, a growth of approxi-

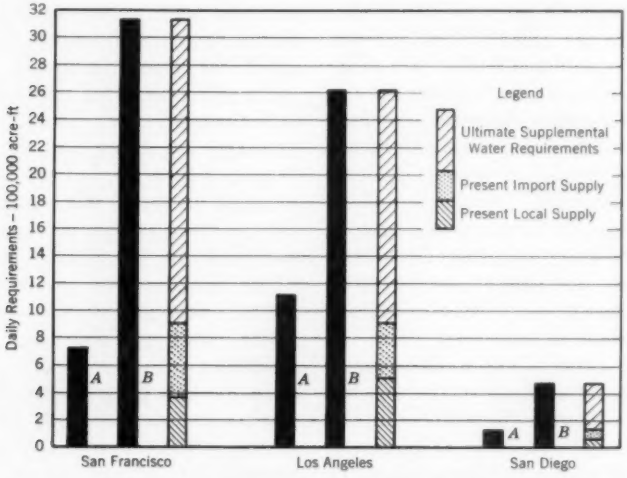

Fig. 1. Water Requirements of California Metropolitan Areas

Bars A *and* B *show present (1950) and ultimate requirements respectively for the three great Californian metropolitan areas. The ultimate supplemental requirements will be partly available through present import sources.*

mately 912,000 people (22 per cent). The water service area increased 36,000 acres even though there was considerable change from agricultural to urban use. The total urban area increased 82,000 acres, as compared to a decrease in agricultural acreage of 46,000 acres. It was thereupon determined that during this 5-year period, the increased water requirement was 108,000 acre-ft, even though there had been a substantial change from agricultural to urban use. If it is assumed that 1 acre-ft serves six persons for 1 year, the 912,000 new people would have increased the water requirement 152,000 acre-ft instead of 108,000 acre-ft.

Historically, agricultural use of land in Los Angeles County reached a peak in 1926, and is now decreasing at a rapid rate. The survey of the areal change in land use in Los Angeles County during the 1950–1955 period indicates that the principal areas of urban expansion are in the San Fernando Valley, the East San Gabriel Valley, the Lakewood-Whittier area, and on the coastal plain from Santa Monica to Long Beach. It is also significant to note that under full development it is expected that the Los Angeles area will require almost twice the water supply being used today.

San Diego Area

The State Department of Water Resources recently made some studies of alternate aqueduct routes to San Diego County (*3*). The general procedure followed in estimating the future demands for imported water in that investigation included an economic study of the area in order to evaluate the relationship of the present levels of agricultural, commercial, and industrial development to the size and distribution of population, as well as the extent of utilization of irrigable and habitable lands. The study also included an estimate of future development of irrigated agriculture, commerce, and in-

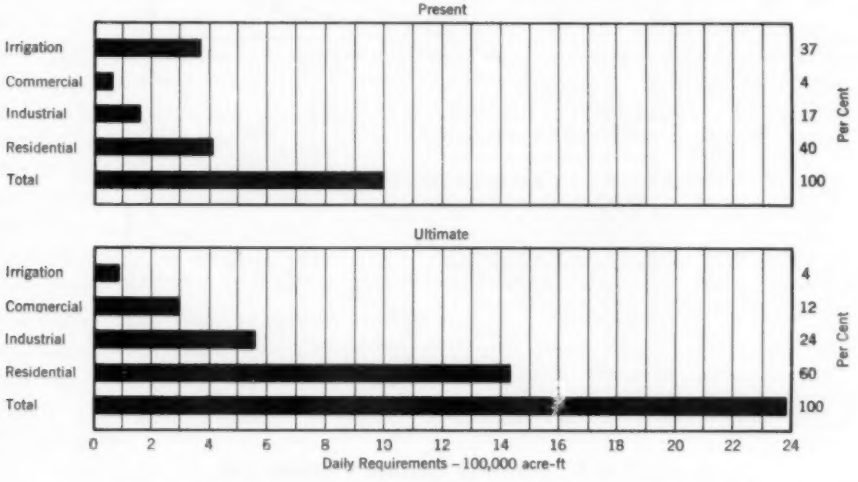

Fig. 2. 1950 Los Angeles Metropolitan Area Water Requirements

dustry in the area. In estimating future demands for the imported water in the metropolitan area of San Diego County, estimates of future population growth based on previously evaluated economic factors were of particular significance. It was estimated that the population growth would increase from 800,000 persons in 1960 to 2,200,000 in 2000. This amounts to an increase of 1,400,000 persons during the 40-year period, or an annual average increase of 35,000 persons. The population of the San Diego metropolitan area is thus expected to be double in the next 25 years.

The expected daily demand of the metropolitan area of San Diego County in 1960 is 120 mil gal. By 2000, it is estimated that 440 mil gal will be required daily. In San Diego County as a whole, the water requirements are expected to increase from an estimated 220 mgd in 1960, to a total of 810 mgd by the year 2000. To meet these water requirements, there is available to the county a local water supply of approximately 100 mgd (if operated on a safe yield basis), and imported supplies, available through the present Colorado River Aqueduct, which can deliver another 120 mgd, making a

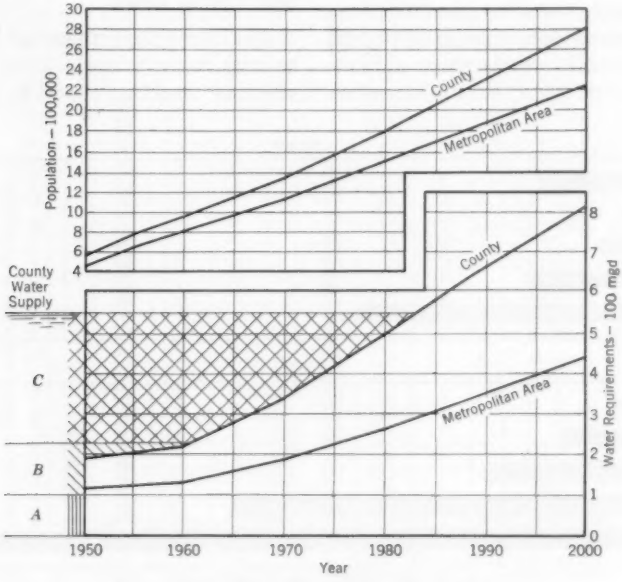

Fig. 3. San Diego Population Growth and Required Water Supply

Besides showing population and water requirement expectations, the diagram also shows the proportion of present and future supplies. The shaded section labeled A *represents local supplies; that labeled* B *is the present Colorado River Aqueduct; and* C *is the proposed second Colorado River aqueduct.*

total supply to the county through present facilities equal to approximately 220 mgd, or the approximate water requirement of 1960. Water shortages exist at the present time because local supplies have not been operated on a safe yield basis. The Metropolitan Water District of Southern California has announced its intentions of constructing a second Colorado River aqueduct to San Diego County. This will consist of a canal in the first portion of the aqueduct having a capacity of 500 cfs, and an initial construction of a closed aqueduct from the canal having a capacity of 250 cfs. As shown in Fig. 3, a 500-cfs capacity aqueduct would meet the projected water demands up to the year 1983. The second barrel on the proposed second Colorado River aqueduct would be required by 1972, or about 12 years after completion of the initial unit. This estimated rapid rate of growth and projection of increased water demands may well serve as an example of what may be expected in other urban areas in California.

Future Urban Needs

Estimates of the quantities of additional water supplies which will be needed to meet future water requirements and the rapid rates at which these increases may be expected to occur have been discussed. It was also shown that the principal metropolitan centers in California are already largely dependent on imported supplies, so that the additional water supplies must be met by increased importations. Projects for water development which will satisfy increased importations are included in the California Water Plan. The data presented further demonstrates the need for implementation of construction of the initial units of the California Water Plan at an early date.

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How Probable Is the Most Probable Number?

Richard L. Woodward

A contribution to the Journal by Richard L. Woodward, Chief of Water Supply, Water Supply and Water Pollution Program, Robert A. Taft San. Eng. Center, USPHS, Cincinnati, Ohio.

THE fermentation tube test is the commonest method in use for estimating the concentration of coliform organisms in water. Although the recently introduced membrane filter technique promises to replace the fermentation tube test in many applications, the dilution test will continue to be widely used.

McCrady (*1*), in 1915, introduced the concept of the Most Probable Number (MPN) for estimating bacterial densities from the results of dilution tests. In the 40 years since then this procedure has been all but universally adopted, and an extensive literature on the theory and use of this method of estimation has developed (*2*).

This study of MPN estimates has two objectives:

1. To determine the probability of obtaining particular results from the three-tube and five-tube tests in multiple decimal dilutions. It is well known that some results occur with relatively great frequency while other results are uncommon. Too frequent occurrence of ordinarily rare results is indicative of some disturbing influence and can be used as a check on technique.

2. To determine confidence limits for use in connection with MPN estimates obtained from a five-tube test using one dilution (as is standard practice on finished drinking waters) and on three-tube and five-tube tests in multiple decimal dilutions. These three types of tests are by far the most common ones from which MPN estimates are made.

Probability of Results

The results of multiple decimal dilution bacteriological tests can be expressed in terms of a set of numbers or code made up of the number of positive tubes in each dilution arranged in order of decreasing sample volume (or increasing dilution) per tube. In a five-tube test, for example, each of which has three dilutions with 10, 1 and 0.1 ml of sample per tube, a common result might be: Five of the five 10-ml tubes are positive; three of the five 1-ml tubes are positive; and none of the five 0.1-ml tubes is positive. The code for this test would be 530. Table 21b of *Standard Methods* (*3*) shows the MPN estimates corresponding to each of the possible results of a five-tube test in these decimal dilutions expressed in terms of this code.

As the quantity of sample in each tube decreases by a factor of ten from one dilution to the next, the number of positive tubes per dilution normally decreases from dilution to dilution. This is not always so, however. The result of a test, for example, in which five of five 10-ml tubes are positive, none of five 1-ml tubes is positive, and one of five 0.1-ml tubes is positive (Code 501)

is not uncommonly found in routine water analysis. On the other hand, the result in which none of the five 10-ml tubes is positive, none of the five 1-ml tubes is positive, and five of the five 0.1-ml tubes are positive (Code 005) would intuitively be regarded with suspicion. It is extremely unlikely (the expected frequency of this result is less than one in one trillion) that all tubes containing 0.1 ml of sample show positive results when none of the tubes containing 10 ml or 1 ml of sample was positive, unless some disturbing influence was active. An MPN can be computed for this code (it is 9 per 100 ml), but such a number would have little real significance because of the extreme unlikelihood that such a code would occur if the assumptions upon which the MPN estimate are based are met. Rather than record an MPN for such a result one should disregard the test entirely. If such codes occur frequently, a search should be made for the cause of the unlikely results.

One can intuitively prepare a list of the more probable results, but, without recourse to mathematical methods, it is not possible to make quantitative statements about the relative probability of various codes. The aim of the study at the Taft Sanitary Engineering Center has been to make possible such quantitative statements.

Halvorson and Moglein (*4*) have studied this problem for a ten-tube multiple decimal dilution test and have presented a list of 94 codes which would include 98.79 per cent of the results from such tests. The method used in the present study differs somewhat from theirs.

For any fixed bacterial density the probability of obtaining various codes can be computed by simple though laborious computations. If this is done for a number of fixed densities, a series of probabilities of occurrence for each code at the several densities is obtained. Although the frequency of occurrence of any one code varies markedly with the bacterial density, the relative frequency of occurrence of a group of common codes is found to vary only slightly with changes in bacterial density.

In studies of the kind considered here, certain codes are assumed to be identical. The codes No. 551, 510, and 100 in a five-tube test, for example, are considered to be essentially the same. The result one actually obtains depends on what quantity of sample was planted in the lowest dilution. If five dilutions are used, for example, and one obtains the code 55100, any one of the three codes previously mentioned could be used to determine the MPN. For this reason calculations of probabilities of the various codes need to be computed over a range of densities covering only one cycle on a logarithmic scale. In this study the densities used ranged from 0.10 per milliliter to 0.95 per milliliter, with increments of 0.05 per milliliter. By using a five-dilution code it was possible to have all codes having any appreciable probability of occurrence begin with all tubes positive and end with all tubes negative. By including only those codes with a probability greater than 0.0005 at a given density it was possible to obtain a group of codes which would account for well over 99 per cent of all results at each density.

Table 1 shows the codes for three-tube and five-tube tests which would account for 99 per cent of the results. No code of more than three numbers was included among the probable results. In other words, a code such as

4201 would be an improbable code with a five-tube test. Halvorson and Moglein (*4*) found that some such four-number codes were included among the more probable results when ten tubes were used in each dilution.

The useful codes are divided into three classes. In Class 1, which occurs most frequently, the transition from all positive to all negative tubes occurs in not more than one dilution. The Class 2 codes include those in which there are

TABLE 1

Five-Tube and Three-Tube Codes That Include 99 Per Cent of All Results

Group	Theoretically Expected Percentage of Results	Theoretically Expected Cumulative Percentage	Observed Percentage of 360 Samples
	Five-Tube Test		
Class 1 codes 550, 551, 552, 553, 554, 500, 510, 520, 530, 540, 100, 200, 300, 400.	67.5	67.5	68.0
Class 2 codes 511, 521, 531, 541, 542, 110, 210, 310, 410, 420.	23.6	91.1	23.1
Class 3 codes 501, 010, 532, 320, 522, 220, 543, 430, 120, 533, 330, 502, 020, 544, 440, 301, 401, 431, 201, 411, 101, 311, 421, 211, 001.	7.9	99.0	7.5
Improbable codes	1.0	100.0	1.4
	Three-Tube Test		
Class 1 codes 330, 331, 332, 300, 310, 320, 100, 200.	81.5	81.5	81.7
Class 2 codes 321, 311, 301, 210, 110, 010.	14.9	96.4	14.1
Class 3 codes 322, 220, 201, 101, 312, 120.	2.7	99.1	3.7
Improbable codes	0.9	100.0	0.6

two dilutions which are not all positive or all negative, and each of which can be expected to occur more than 2 per cent of the time. The Class 3 codes are less frequent ones which, together with those of the first two classes, should make up 99 per cent of all results. Only 49 of the 214 possible five-tube codes, and 20 of the 62 possible three-tube codes are included in the useful list, excluding also the indeterminate results in which the tubes are either all positive or all negative. If one thus rejects all determinate codes not in Table 1, one should, in the long run, reject only 1 per cent of the tests.

Table 1 also shows the theoretical and actual results for a series of bacteriological tests made in the Robert A. Taft Sanitary Engineering Center laboratories. The agreement with the expected values is quite good.

The code classification affords a relatively rapid method of checking on the possible presence of disturbing influences in the performance of coliform MPN tests. The aberrations may be due to improper technique, substances in the water which inhibit growth or gas production by the coliform group, or the antagonistic effect of growth products of the noncoliform bacterial flora. Unduly large numbers of improbable codes would indicate some such influence to be active. As one would not expect to find precisely 1 per cent of the results in a group of tests giving improbable codes, and as it would be uneconomical to look for trouble where none exists, a maximum number of improbable codes has been computed for various numbers of samples; these codes should be exceeded before trouble is suspected and sought. These figures are shown in Table 2. They are intended to insure against "crying wolf" more often than one time in a hundred.

TABLE 2

Maximum Permissible Numbers of Improbable Codes for Various Numbers of Samples Tested

Number of Samples	Maximum Number of Improbable Codes
1– 15	1
16– 45	2
46– 83	3
84–130	4
131–180	5
181–233	6
234–290	7
291–350	8
351–413	9
414–477	10
478–543	11

A simple method for using this scheme would be to use tables showing MPN values only for those codes listed in Table 1. Tables 3 and 4 provide this information as well as confidence limits for the MPN estimates. No MPN would be recorded for the improbable results. Some other distinctive mark (a question mark, for example), could be recorded instead. Inspection of summary sheets of results would readily show whether an undue number of improbables are occurring. Indeterminate results, either all negative or all positive, should be omitted entirely from the numbers used in computing the percentage of improbable results.

Confidence Limits

The lack of precision of MPN estimates of bacterial densities is generally recognized—at least by those who perform the tests. Like many other measurements used and interpreted by others than the laboratory workers who

fashion them, MPN estimates are often credited with a precision they do not deserve. The problem of the reliability of MPN estimates has been studied extensively. Eisenhart and Wilson (*5*) have most ably reviewed the work done on this problem. They have shown that the logarithms of the MPN estimates for a ten-tube multiple dilution test at a given bacterial density are approximately normally distributed with a mean value close to the logarithm of the given bacterial density and with a standard deviation which does not vary greatly with the bacterial density.

Confidence limits for the MPN estimates can be computed on the basis of a logarithmically normal distribution. It has been verified that the three-tube and five-tube MPN estimates are approximately logarithmically normal and that the standard deviation of the logarithms of the MPN's is given by the formula:

$$\left\langle \sigma(\log) = \frac{0.55}{\sqrt{N}} \right\rangle$$

where $\sigma(\log)$ is the standard deviation of the logarithm of the MPN values and N is the number of tubes in each dilution. Velz (*6*) has also used this approximation and verified the facts on which it is based. Table 5 shows ap-

TABLE 3

Precise Confidence Limits for MPN per 100 ml of Sample *

Three-Tube Code	MPN	50% Confidence Limits		90% Confidence Limits		95% Confidence Limits	
		Lower	Upper	Lower	Upper	Lower	Upper
333	—	1,600	—	620	—	460	—
332	1,100	460	2,400	190	4,100	150	4,800
331	460	180	1,100	91	2,000	71	2,400
330	240	100	490	48	1,000	36	1,300
322	210	97	240	46	400	35	470
321	150	79	230	38	380	30	440
320	93	41	190	19	330	15	380
312	120	78	190	38	330	30	380
311	75	37	110	17	200	14	230
310	43	18	98	9.1	180	7.1	210
301	39	18	48	8.8	99	6.9	130
300	23	10	45	4.6	91	3.5	120
220	21	9.7	24	4.6	40	3.5	47
210	15	7.9	23	3.7	38	2.8	44
201	14	7.8	19	3.6	32	2.7	37
200	9.1	3.9	18	1.5	31	1.0	36
120	11	7.7	19	3.6	31	2.7	36
110	7.3	3.5	11	1.3	20	0.88	23
101	7.2	3.4	9.8	1.3	18	0.87	21
100	3.6	0.9	9.6	0.17	18	0.085	20
010	3.0	0.88	4.6	0.17	9.9	0.085	13
000	—	0	2.1	0	6.9	0	9

* Using three tubes per dilution with 10, 1, and 0.1 ml volume per tube.

TABLE 4

Precise Confidence Limits for MPN Per 100 ml of Sample *

Five-Tube Code	MPN	50% Confidence Limits		90% Confidence Limits		95% Confidence Limits	
		Lower	Upper	Lower	Upper	Lower	Upper
555	—	1,400	—	1,000	—	800	—
554	1,600	790	2,900	430	4,600	350	5,300
553	920	450	1,700	250	2,600	210	3,000
552	540	280	1,000	160	1,700	130	2,000
551	350	180	620	100	1,100	89	1,400
550	240	140	360	79	620	65	740
544	350	180	380	100	630	89	760
543	280	180	370	100	630	88	750
542	220	130	280	75	430	62	490
541	170	110	250	61	390	50	440
540	130	77	200	42	310	35	360
533	180	130	250	74	390	62	440
532	140	100	210	58	320	48	370
531	110	66	160	37	240	30	280
530	79	45	140	25	210	21	240
522	95	64	140	36	220	29	240
521	70	41	100	23	170	19	190
520	49	27	88	16	150	13	180
512	64	40	88	23	150	19	180
511	46	26	61	15	110	12	130
510	33	18	55	10	95	8.9	120
502	43	26	56	15	96	12	120
501	31	18	37	10	63	8.8	74
500	23	14	34	7.9	58	6.5	68
440	34	26	55	15	95	12	120
430	27	17	35	10	59	8.6	69
421	26	17	35	10	58	8.6	68
420	22	13	28	7.5	42	6.3	49
411	21	13	25	7.5	39	6.2	44
410	17	11	25	6.1	38	5.5	43
401	17	10	21	6.0	32	5.0	36
400	13	7.6	20	4.1	30	3.3	35
330	17	10	20	6.0	31	5.0	35
320	14	10	20	5.9	31	4.8	35
311	14	9.9	20	5.8	30	4.7	35
310	11	6.6	15	3.5	24	2.8	28
301	11	6.5	14	3.5	21	2.8	24
300	7.8	4.4	13	2.1	20	1.6	24
220	9.3	6.4	14	3.4	21	2.8	24
211	9.2	6.3	14	3.4	20	2.8	24
210	6.8	3.9	10	1.9	16	1.4	19
201	6.8	3.9	8.9	1.8	15	1.4	17
200	4.5	2.2	8.7	0.80	14	0.55	17
120	6.1	3.8	8.8	1.8	15	1.4	17
110	4.0	1.9	6.0	0.71	11	0.49	13
101	4.0	1.9	5.4	0.70	9.5	0.49	12
100	2.0	0.57	5.3	0.10	9.5	0.052	12
020	3.7	1.9	5.4	0.70	9.5	0.49	12
010	1.8	0.53	2.8	0.093	5.9	0.047	7.3
001	1.8	0.52	2.5	0.093	5.5	0.047	6.7
000	—	—	1.3	—	4.2	—	5.4

* Using five tubes per dilution with 10, 1, and 0.1 ml volumes per tube.

proximate confidence limits for bacterial densities based on the logarithmically normal assumption. As the MPN estimate is biased, these confidence limits are not symmetric about the MPN estimate.

Although this approximation is undoubtedly a good one when relatively large numbers of tubes are used in each dilution, there is reason to check its accuracy when only three or five tubes are used in each dilution. The MPN values obtained from dilution tests are a discrete set of numbers, and when only three or five tubes are used, the set is quite small. Errors are introduced when one approximates a discrete distribution with a continuous one such as the normal distribution, particularly if the number of discrete values with any appreciable probability is small.

Precise confidence limits have, therefore, been computed for the three- and five-tube tests. The results are shown in Tables 3 and 4. A similar computation has been made for the five-tube test in a single dilution, the most common test on drinking water. The results are shown in Table 6. The method used to compute these confidence limits is outlined elsewhere (*5, 7*).

Table 5, for instance, shows approximate 95 per cent confidence intervals for a three-tube test to be from 21 to 395 per cent of the estimated MPN. That is, if one states that the true bacterial density of a sample examined by a three-tube test in each of the three dilutions is between 21 and 395 per cent of the MPN as determined from the test results, he will be right about 95 per cent of the time.

The precise confidence limits shown in Table 3 do not bear a constant percentage relationship to the MPN. The lower 95 per cent confidence limits range from 2.8 to 25 per cent of the MPN, and the upper 95 per cent confidence limits range from 224 to 555 per cent. In general, the precise limits are broader than the approximate ones. A weighted average of these percentages, using as weighting factors the relative frequency of the various results, gives average 95 per cent confidence limits of 14 per cent and 458 per cent.

Similarly, for the five-tube test, the approximate 95 per cent confidence limits are 31 and 289 per cent, while

TABLE 5

Approximate Confidence Limits for Bacterial Densities

Number of Tubes in Each Dilution	Confidence Limits—*per cent of MPN*					
	50% Confidence		90% Confidence		95% Confidence	
	Lower	Upper	Lower	Upper	Lower	Upper
1	33	186	10	637	6.5	955
2	47	160	20	383	15	511
3	53	150	26	311	21	395
5	64	139	37	241	31	289
10	76	127	52	184	46	208

the weighted means of the percentages of MPN of the precise 95 per cent confidence limits are 24 and 324 per cent.

In using Tables 3, 4, and 6, the limits and MPN values are based on tests using 10 ml of sample per tube in the lowest dilution. If smaller (or larger) quantities are used, the values in these tables are simply multiplied by the appropriate factor. Thus, if the 1, 0.1, and 0.01 ml volumes are used, the values in Tables 3 and 4 should all be multiplied by ten.

If one wishes to define only upper or lower confidence limits, the values for example, shows 4,600 as the upper 90 per cent confidence limit for the code 554, and 430 as the lower 90 per cent confidence limit. If one places no lower limit on the true density, the upper 95 per cent confidence limit corresponding to the result 554 is 4,600 per 100 ml, and if one places no upper limit on the true density, the lower 95 per cent confidence limit is 430 per 100 ml.

It should be pointed out that it is inherent in confidence limits that no *single* confidence interval can be considered to include the true value with

TABLE 6

Precise Confidence Limits in Bacteria per 100 ml *

No. of Positive Tubes	MPN	50% Confidence Limits		90% Confidence Limits		95% Confidence Limits	
		Lower	Upper	Lower	Upper	Lower	Upper
0	—	0	1.4	0	4.6	0	6.0
1	2.2	0.5	6.1	0.1	10.7	0.05	12.6
2	5.1	2.2	10.2	0.8	16.6	0.54	19.2
3	9.1	4.4	16.4	2.1	25.7	1.6	29.5
4	16.0	7.9	28.8	4.2	45.8	3.3	52.9
5	—	20.4	—	10.0	—	8.0	—

* When using five tubes and a single dilution.

in Tables 3, 4, and 6 can be used with appropriate changes in the confidence to be attached to them. This applies only to the determinate results. With indeterminate results that are all positive, one can compute only a lower confidence limit, and with an entirely negative result, only an upper limit. For the determinate results one can use the upper confidence limits shown in the 50 per cent column with 75 per cent confidence, those in the 90 per cent column with 95 per cent confidence, and those in the 95 per cent column with 97.5 per cent confidence, if one makes statements only about the upper limit of the true bacterial density. Table 4,

the specified degree of certainty, but that the statements apply properly to all of the intervals as a group. In Table 6, for instance, the 95 per cent upper confidence limit for a result in which no tube in five is positive is 6.0. This does not assure that, if each time this result is obtained one states "the true density is less than 6.0," he will be right 95 per cent of the time. The percentage of the time that this particular statement is true depends upon the percentage of the time that the true density is more than or less than 6.0. If all six statements in Table 6 corresponding to the six possible results with a five-tube single dilution test, are

considered, however, and if these statements are made whenever the corresponding result is obtained, the statements will, *as a group,* be true 95 per cent (or 50 or 90 per cent) of the time regardless of the relative frequency with which various true densities occur. This is further discussed elsewhere (*5, 7*).

Summary

Forty-nine of the possible 214 determinate codes from a five-tube MPN test in three or more decimal dilutions account for 99 per cent of all codes from such tests in the absence of disturbing influences such as faulty technique or the presence of inhibitory substances in the water being tested. For a similar three-tube test, 20 of the 62 possible test results account for 99 per cent of all results. Too frequent occurrence of the improbable tube combinations can be used as a check on the reliability of the results.

Precise confidence limits have been computed for three-tube and five-tube tests using multiple decimal dilutions and for the five-tube single dilution test. These limits are broader than the approximate ones based on a log normal distribution of MPN's. For a three-tube multiple dilution test, the 95 per cent confidence limits cover approximately a 33-fold range from approximately 14 to 458 per cent of the MPN estimate. For a five-tube multiple dilution test, the 95 per cent confidence limits cover approximately a thirteenfold range from approximately 24 to 324 per cent of the MPN. In short, MPN estimates are not precise and many of them are inherently improbable.

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Use of Radioactive Culture Media

Gilbert V. Levin, Venton R. Harrison, and Walter C. Hess

A paper presented on May 14, 1957, at the Annual Conference, Atlantic City, N.J., by Gilbert V. Levin, San. Engr., Resources Research Inc., Washington, D.C.; Venton R. Harrison, Bacteriologist, School of Medicine, Georgetown University, Washington, D.C.; and Walter C. Hess, Asst. Dean of Research and Prof. of Biochemistry, School of Medicine, Georgetown University, Washington, D.C.

SINCE the use of radioactive culture media in a rapid presumptive test for coliform organisms was first reported in the JOURNAL (*1*), significant changes in method and equipment have been made. Experiments have been conducted with several different culture media, and work has begun toward a rapid confirmed test.

Before proceeding with a discussion of current work, however, a brief review of the general principles of the method might be of assistance to those unfamiliar with it. The rapid presumptive test relies upon the same criteria for the presumptive identification of coliform organisms as does the one outlined in *Standard Methods* (*2*)—namely, the ability of coliform organisms to ferment lactose with the production of gas. The difference between the two tests lies in the means of detecting the gas. In the *Standard Methods* procedure, sufficient gas produced by the organisms must accumulate until a visible bubble is evident. This requires from 24 to 48 hr of incubation. If the gas is made radioactive, however, extremely small quantities of it can be detected. The time required for the determination is thus greatly reduced.

A large portion of the gas produced from lactose by coliform organisms is carbon dioxide. By substituting radioactive carbon in the lactose, the carbon dioxide produced by the organisms can be made radioactive. Thus, if a sample of unidentified bacteria is placed in standard lactose broth (*2*) prepared with radioactive lactose and then incubated at 37°C, the evolution of radioactive carbon dioxide constitutes a positive presumptive test for coliform organisms. In actual practice, the amount of radioactivity evolved from a test sample is compared to that evolved from a sterile control. The comparison is necessary because a small quantity of radioactive carbon dioxide is evolved from sterile radioactive lactose. If the radioactivity evolved by the test sample is significantly higher than that evolved by the sterile control, the test is positive.

Presumptive Test

The unit shown in Fig. 1 is the combined bacteriological culture and carbon dioxide trapping device developed for the rapid test. The sample of water to be tested is filtered through a small membrane filter. The filter is then placed in the metal cup or planchet

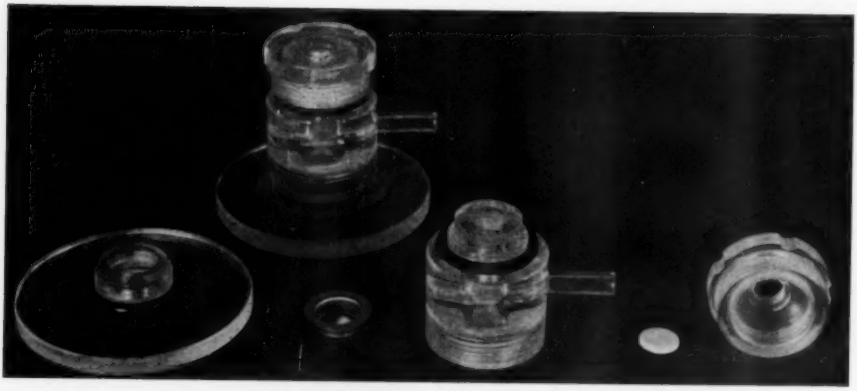

Fig. 1. Combination Culture and $C^{14}O_2$ Collection Unit

The components of the unit (foreground) are shown, left to right, in the order in which they are assembled—base, culture cup, middle section, paper pad, and top section. A fully assembled unit is shown slightly behind the parts.

Fig. 2. Counter and Scaler

The modified Robinson gas-flow counter is shown to the left, with two planchets ready to be placed in it. The scaler is to the right, and the tank supplying the counting gas is to the rear.

which fits into the base section of the plastic unit. A pipet is used to place 0.1 ml of the radioactive lactose broth on the filter. The middle section of the unit, consisting of a chimney with an air tube projected into it, is then screwed tightly onto the base. A paper pad is fitted into the top section and is wetted with one drop of a saturated solution of barium hydroxide. The top section is then screwed on, thus completing the assembly of the unit, and the base of the unit is immersed in a 37°C water bath. Filtered air from the laboratory compressed air line is introduced into the air tube of the middle section. The aeration rate is maintained at approximately 5 ml per minute by bubbling the air through mineral oil. The portion of the tube traversing the chimney has three small holes which direct the air downward to the broth. The air sweeps the surface of the broth, entraining any carbon dioxide that had diffused to the surface, and carrying it up the chimney. The carbon dioxide is deposited on the pad as barium carbonate. The remaining gases pass through the pad. After the desired interval has elapsed, the top section is removed and the pad is placed, exposed side up, in a small planchet. The pad is dried by placing the planchet under a heat lamp for 10 min. The planchet containing the pad is then placed into the modified Robinson gas-flow counter, shown in Fig. 2, and measured for radioactivity. A counting period of 5 min has been adopted. The culture and collection apparatus currently in use is shown in Fig. 3. A manifold supplies air, metered through the vertical test tubes of mineral oil, to as many as sixteen units simultaneously.

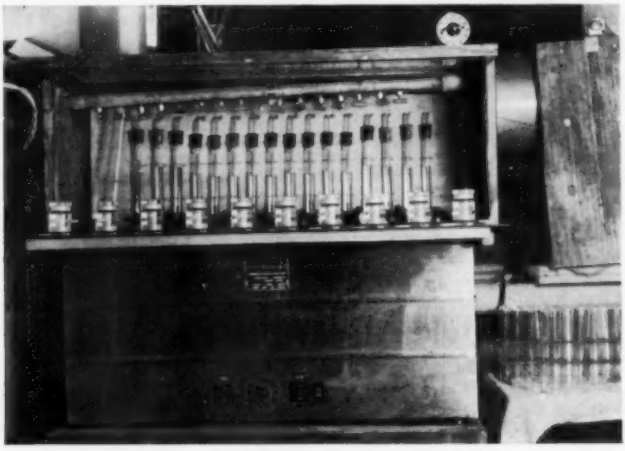

Fig. 3. Bank of Units

A manifold supplies laboratory air through the needle valves to the test tube bubble meters, and thence to the units. Ten units are shown on the work shelf prior to partial immersion in the water bath for 37°C incubation. The apparatus can handle sixteen units simultaneously.

The radioactive lactose is 1-C^{14} lactose synthesized at the National Bureau of Standards (*3*). It has been obtained with specific activities varying from 1.79 to 5.46 microcuries (μc) per milligram. Thus, when lactose with a specific activity of 5.46 μc per milligram is used, 0.1 ml of a 0.5 per cent solution—the standard method concentration—contains a total of 2.73 μc which is the amount of radioactivity used per test. Current AEC regulations permit purchase of 500 μc of C^{14} without requiring the purchaser to obtain a license or equip the laboratory in any special fashion. The use of 1-C^{14} lactose in the rapid presumptive test for coliform organisms was recently described (*4*) in the literature.

Broth Strength Variances

Quantities of a 1-C^{14}-lactose broth were prepared in various strengths to determine if increased concentrations of available lactose would increase CO_2 production by the organisms. In a massive inoculation experiment, *Esch. coli* were incubated in nutrient broth at room temperature for 16 hr. A 0.5-ml portion of the culture was transferred to 5.0 ml sterile tap water and held at room temperature for 24 hr. One drop of this suspension (10^6 to 10^8 cells) was used to inoculate each of the presumptive test cultures. The method used has already been described (*4*). Concentrations of 0.5, 1, 2, and 3 per cent 1-C^{14} lactose, each in three replicates, were run for 1 hr. The results are shown in Table 1. The effect of increased lactose concentration is readily apparent in the table. In the interests of conservation of isotope, the concentration effect has not been pursued to its maximum.

TABLE 1

Effect of Concentration of 1-C^{14} Lactose on $C^{14}O_2$ Production*

Time After Inoculation *min*	Radioactivity of Evolved $C^{14}O_2$ *cpm*†											
	Concentration—*0.5%*‡			Concentration—*1%*‡			Concentration—*2%*‡			Concentration—*3%*‡		
15	1,041	1,107	843	1,304	1,610	2,129	3,495	1,838	3,231	3,471	3,280	3,014
30	2,346	2,222	1,913	2,573	2,533	2,416	5,900	5,735	5,515	5,629	5,260	4,424
45	442	377	362	422	311	433	2,132	1,656	1,460	4,947	4,341	2,887
60	84	100	102	103	79	110	443	371	417	3,337	4,210	3,639
Total	3,913	3,806	3,220	4,402	4,533	5,088	11,970	9,600	10,623	17,384	17,091	13,964
60-min Average	3,646			4,674			10,731			16,146		

* Produced with equally massive *Esch. coli* inocula.
† Radioactivity was measured above a background of 7 cpm.
‡ Three replicates of the same concentration were used.

To test the concentration effect on low numbers of *Esch. coli* cells, a suspension was prepared essentially as that just described. Prior to inoculation, the suspension was serially diluted 10^7 fold. One drop of this suspension was inoculated into each of the test cultures. Plate count determinations revealed the presence of approximately 5 cells per test. Concentrations of 3, 4, and 5 per cent 1-C^{14} lactose, each in

three replicates, were run for 1 hr. Three sterile controls were run using 5 per cent 1-C^{14} lactose concentration. The highest concentration was used for the control since it would produce the highest nonmetabolic evolution of $C^{14}O_2$. Thus all test to control comparisons would be conservative. The results are shown in Table 2, in which the effect of concentration is again evident. A total of eight 1-hr runs, containing 61 inoculated replicates, was made in which the concentration of 1-C^{14} lactose varied between 1 and 5 per cent, and the size of inocula varied between 5 and 200 lag-phase cells. Forty-two of the replicates produced quantities of $C^{14}O_2$ significantly above that of their sterile controls. The nineteen replicates that did not produce positive results contained concentrations of 1-C^{14} lactose of 2 per cent or less.

TABLE 2

Effect of Concentration of 1-C^{14} Lactose on $C^{14}O_2$ Production*

Time After Inoculation *min*	Radioactivity of Evolved $C^{14}O_2$ *cpm*†											
	Inoculated Tests									Sterile Controls		
	Concentration—*3%*‡			Concentration—*4%*‡			Concentration—*5%*‡			Concentration—*5%*‡		
15	69	59	65	82	74	95	133	102	116	77	53	89
30	77	67	63	84	65	83	115	93	101	64	37	65
45	61	45	35	53	46	55	67	48	65	39	22	36
60	61	38	40	53	38	49	71	50	71	41	22	33
Total	268	209	203	272	223	282	386	293	353	221	134	223
60-min Average	227			259			344			193		

* Produced with approximately 5 *Esch. coli* cells per test in 1-C^{14} Lactose broth.
† Radioactivity was measured above a background of 7 cpm.
‡ Three replicates of the same concentration were used.

pH Effect

The influence of pH on the test has been found to be pronounced from a biological and a chemical point of view. Inoculation into 1-C^{14} lactose broth at pH 8 has been found to produce the greatest quantity of metabolic CO_2. Increases of as much as 100 per cent over quantities of CO_2 produced by equal inocula at initial pH 6 or 7 have been found when massive inocula were used. At the end of the 1-hr run, the final pH in such tests has been found to be acid due to the metabolism of the organisms. Massive cultures thus enjoy the initial advantage of biological activity at pH 8 and the subsequent chemical advantage of the acid pH in liberating from solution the CO_2 produced. The chemical effect, however, works against light inocula tests since there are insufficient organisms present to lower the pH to the acid range. Much of the CO_2 produced by the organisms thus remains in solution as the bicarbonate ion. It may be possible to allow the cultures to metabolize for 1 hr, or some desired period, and then to add acid to liberate the dissolved CO_2 for subsequent immediate collection.

Confirmatory Media

The *Standard Methods* (*2*) procedure requires that the confirmed test for coliform organisms be made subsequent to the presumptive test. The confirmed test cannot be made directly, because, in addition to being inhibitory to noncoliform organisms, the confirmatory media are also somewhat inhibitory to coliform organisms. There are, usually insufficient coliform organisms present in a water sample to overcome or survive this effect. The organisms are thus cultured to high densities in the fairly selective presumptive medium and a massive inoculum is then transferred to the confirmatory medium. It seemed possible that a small inoculum of coliform organisms might survive and respire in the confirmatory media long enough to be detected by the radioisotope method. If this were the case, a rapid confirmed test might be made directly from the water sample. In this event, time could be saved by shifting efforts to refine the method from the presumptive to confirmatory media. To explore this possibility, tests were made using various confirmatory media incorporating radioactive compounds.

A crystal violet broth containing 1-C^{14} lactose, a brilliant green bile broth containing 1-C^{14} lactose, and a formate ricinoleate broth containing C^{14} formate were prepared. Each of the media was made in accordance with the *Standard Methods* procedure (*2*). Exponentially growing *Esch. coli* cells inoculated into these media were able to survive sufficiently long to yield $C^{14}O_2$ in excess of the sterile control levels. Approximately 100 cells inoculated into three replicate crystal violet broth cultures produced an average of 48 counts per minute (cpm) on the $C^{14}O_2$ collection pads in 1 hr, as opposed to an average of 38 cpm for three sterile controls. In a serial dilution test of *Esch. coli* in C^{14} formate ricinoleate broth, the cutoff point for statistical significance within a 1-hr test period occurred at the dilution containing approximately 18,000 cells, averaging 179 cpm for test portions compared to an average of 135 cpm for the controls. The nonmetabolic evolution of $C^{14}O_2$ was higher from the formate than from 1-C^{14} lactose. The formate, however, was of higher specific activity, containing 35.8 μc per test portion. Results with exponentially growing cells in 1-C^{14} lactose brilliant green bile broth have shown sensitivity to approximately 15,000 cells in 1 hr. As work has just begun with the confirmatory media, no results are yet available with lag-phase cells.

The ability of *Esch. coli* cells to produce detectable quantities of $C^{14}O_2$ is only one aspect of producing a rapid confirmed test. It must also be shown that lactose fermenting noncoliform organisms will not produce detectable quantities of $C^{14}O_2$ in the confirmatory media. It seems quite probable that lactose fermenting noncoliform organisms might survive the inhibitor sufficiently long to do this. If this is found to be true, it may be possible to delay the $C^{14}O_2$ collection phase of the test sufficiently to allow the noncoliform organisms to die, flush all $C^{14}O_2$ out of the culture, and begin collection in the normal manner.

Nonmetabolic $C^{14}O_2$

The evolution of radioactive carbon dioxide from sterile control portions of radioactive media continues to be the most troublesome difficulty. At times, the level remains essentially at 0 cpm for several consecutive runs, and it

seems the problem is solved. The next run, however, will show that the level has unaccountably soared to 50 or 100 cpm. While being relatively consistent within each run, the unexplained variability of the level of nonmetabolic $C^{14}O_2$ emitted from run to run makes it necessary to include sterile controls in each run. This same defect frequently impairs the sensitivity of the test by adding to the level of radioactivity required for statistical significance of the test results. Work on methods to reduce and control this phenomenon is continuing. The most encouraging development in this direction is the determination that the $C^{14}O_2$ is, at least primarily, produced as the result of a chemical reaction, rather than as a direct product of radioactive disintegration of the lactose. This has been shown by studies of nonmetabolic evolution of $C^{14}O_2$ as a function of temperature of sterile 1-C^{14} lactose broth. In one instance, three sterile 0.1-ml portions of 1-C^{14} lactose were taken from a common pool. Each portion was placed in a separate detection unit and collection of CO_2 begun. The only difference between the three portions lay in the temperatures, which were maintained at 10, 25, and 37°C, respectively. At the end of ½ hr, the collecting pads revealed supraback-ground radioactivity levels of 2.2 cpm, 10.6 cpm, and 16.2 cpm, respectively. These are greater differences than can be accounted for by increased solubility of CO_2 at lower temperatures. Other sterile tests made at approximately 5–7°C have yielded noise levels of 0 cpm for 1-hr periods while high levels were obtained from replicates at 37°C. As radioactive decay rates cannot be affected in any manner by temperature change, these results support the conclusion stated. The process may begin with radioactive degradation products, but then goes through one or more chemical reactions before $C^{14}O_2$ is produced. This conclusion was recently confirmed by other workers (*5*) dealing with tastes produced by irradiation of foods. It might, therefore, be possible to incorporate a reagent into the medium that would arrest the stepwise reaction before the $C^{14}O_2$ is produced.

Summary

The rapid method for the presumptive determination of coliform organisms has been considerably refined since first reported. The principal changes have been in the development of a compact culture and CO_2 trapping unit, and the reduction in the quantity of isotope used per test. Other results of current experiments have shown that:

1. Concentration of lactose in lactose broth has a distinct direct effect upon CO_2 production by *Esch coli*.
2. The pH exerts a pronounced biological and chemical effect upon the test. At pH 8, the organisms produce maximum quantities of CO_2 during the 1-hr test. When the broth is on the alkaline side, however, much of the CO_2 remains in solution in the form of the bicarbonate ion. Addition of a drop of acid at the end of the run might be used to liberate the CO_2.
3. It may be possible to make direct confirmatory determinations by the radioactive method.
4. The nonmetabolic evolution of $C^{14}O_2$ from the sterile 1-C^{14} lactose is the chief immediate problem demanding attention in the development of the test.

Conclusions

The radioisotope method has been found to be capable of remarkable sen-

sitivity to extremely small numbers of *Esch. coli* cells. Results, however, are not uniform. It is believed this is due to some yet unrecognized environmental factors which are not controlled. In addition, emission of $C^{14}O_2$ from the sterile control presents a difficulty of nonbiological origin. If these problems can be overcome, however, it will be possible to obtain results of presumptive, and perhaps, confirmed, coliform tests in 1 or, at most, several hours.

Acknowledgments

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The authors wish to acknowledge the capable assistance of H. C. Gurney.

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Safe Use of Truck-mounted Power Winches

Truck-mounted power winches are employed by public utilities and the construction industries to move, raise, or lower heavy loads, or for general work. To avoid accidents it is as important to learn to operate power winches as it is to learn to drive the truck. A few specific practices and ideas for the safe operation of power winches as prepared by the National Safety Council follow:

1. Persons not familiar with the controls of truck-mounted power winches should first check control lever positions against an instruction plate, which should be mounted in full view of the operator and should indicate various operating positions.

2. A lock or latch should be provided to keep the power takeoff lever in "off" position while the truck is being driven.

3. If a clutch engages so slightly that there is danger of it disengaging, air or vacuum devices can be used to hold it engaged and prevent a load from being dropped.

Proposed Standard Methods for Methane Determination

Committee Report

A report made under the jurisdiction of Committee 8930 P—Standard Methods for the Examination of Water, Sewage, and Industrial Wastes (Michael J. Taras, Chairman), by a subcommittee composed of John R. Rossum (Chairman), Russell E. Frazier, and T. E. Larson.

The Standard Methods Committee of AWWA intends, from time to time, to present proposed methods for various constituents of water. These methods will be presented after appropriate subcommittee and committee consideration for eventual inclusion in the Eleventh Edition of Standard Methods for the Examination of Water, Sewage, and Industrial Wastes. *The objective of this policy will be to encourage the broader use of the new methods with a view to learning their limitations. Comments, suggestions, and criticisms are invited on the tentative method for methane, as well as on all procedures in the Tenth Edition. Please address all pertinent remarks to the American Water Works Association, 2 Park Ave., New York 16, N.Y.*

METHANE is a colorless, odorless, tasteless, and combustible gas occasionally found in underground waters. The escape of this gas from water may develop an explosive atmosphere not only in the utility's facilities, such as tanks and pumphouses, but also on the consumer's property, particularly where water is sprayed through poorly ventilated spaces such as public showers.

The explosive limits of methane in air are 5–15 per cent by volume. At sea level, a 5 per cent methane concentration in air could theoretically be reached in a poorly ventilated space sprayed with hot (68°C) water having a methane concentration of only 0.7 mg/l. At higher water temperatures, the vapor pressure of water is so great that no explosive mixture can form. At lower barometric pressures, the theoretical hazardous concentration of methane in water will be reduced proportionately. In an atmosphere of nitrogen or other inert gas, oxygen must be present at least to the extent of 12.8 per cent.

A qualitative test for high methane concentration can be made as follows: Invert a quart-size bottle of water and immerse the neck of the bottle in a pan or trough of water. Insert a tube or hose from a tap upward, through the mouth of the bottle, and allow the tap water to flow into the bottle, displacing the original water and permitting "gas" to accumulate at the top of the inverted bottle. After approximately an eighth to a fourth of the bottle is filled with "gas," remove the hose, place hand over the mouth of the bottle, and again invert to an upright position holding hand in place. By placing a lighted match at the mouth of the bottle immediately on removing

hand, a brief wisp of blue flame will be apparent within the neck of the bottle if the "gas" is methane in high concentration. This blue flame is best observed in a darkened room. This is not a quantitative test but may indicate as low as 2 mg/l methane (1 cu ft per 1,000 gal). A positive test warrants precautionary measures. A negative test would require a quantitative analysis. The qualitative test should be performed with the utmost care. Every safeguard should be taken against bodily injury which might result from the shattering of the glass container during the flaming operation. Adequate shielding of the container and the wearing of goggles or a face shield are among the elementary precautions to be observed.

Selection of Method. The combustible gas indicator method offers the advantages of simplicity, speed, and great sensitivity. The Orsat analysis can be made more accurate for concentrations of 4–5 mg/l and higher, but will not be satisfactory for very low concentrations. The Orsat method is also applicable in a situation demanding a differentiation between methane and other gases. Such a situation might arise when a water supply is contaminated by a liquid petroleum gas or other volatile combustible materials.

A. Combustible Gas Indicator Method

1. General Discussion

1.1. *Principle.* An equilibrium is established according to Henry's Law between methane in solution and the partial pressure of methane in the gas phase above the solution. The partial pressure of methane may be determined with a combustible gas indicator. The operation of the instrument is based upon the catalytic oxidation of a combustible gas on a heated platinum filament which is made a part of a Wheatstone bridge. The heat generated by the oxidation of the gas increases the electrical resistance of the filament. The resulting unbalance of the electrical circuit causes deflection of a milliammeter. The milliammeter may be calibrated in terms of the percentage of methane or the percentage of the lower explosive limit of the gas sampled.

1.2. *Interference.* Small amounts of ethane are usually associated with methane in natural gas, and presumably would be present in water that contains methane. Hydrogen sulfide may interfere if the pH of the water is low enough for an appreciable fraction of the total sulfides to exist in the unionized form. The vapors of combustible oils may also interfere. In general, these interferences are of no practical importance, as the analyst is primarily interested in calculating the explosion hazard to which all combustible gases and vapors contribute.

Interference due to hydrogen sulfide can be reduced by the addition of solid sodium hydroxide to the container prior to sampling.

1.3. *Sensitivity.* The limit of sensitivity of the test is approximately 0.2 mg/l.

1.4. *Sampling.* If the water is supersaturated with methane, a representative sample cannot be obtained unless the water is under sufficient pressure to keep all of the gas dissolved. Wells should be operated for a sufficient period of time to insure that water coming directly from the aquifer is being sampled. Representative samples can be expected only if the well is equipped with a pump operating at

sufficient submergence to assure that no gas escapes from the water.

2. Apparatus

2.1. *Combustible gas indicator.** A two-way stopcock should be connected to the inlet so that the instrument may be zeroed on atmospheric air immediately prior to obtaining the sample reading. For laboratory use, the suction bulb may be replaced with a filter pump throttled so as to draw gas through the instrument at a rate of approximately 600 ml per minute. A diagrammatic view of the apparatus is shown in Fig. 1.

2.2. *Laboratory filter pump.*

2.3. *A 1-gal glass bottle* fitted with a two-hole rubber stopper. The inlet tube should extend to within 1 cm of the bottom, and the outlet tube should terminate approximately 1 cm from the stopper. The tubes may be metal or glass. Each should be fitted with stopcocks or with short (approximately 5-cm) lengths of rubber tubing and pinchcocks. The entire assembly should be capable of holding a low vacuum for several hours. The volume of the assembly should be determined by filling with water and measuring the volume, or weight, of the water contained.

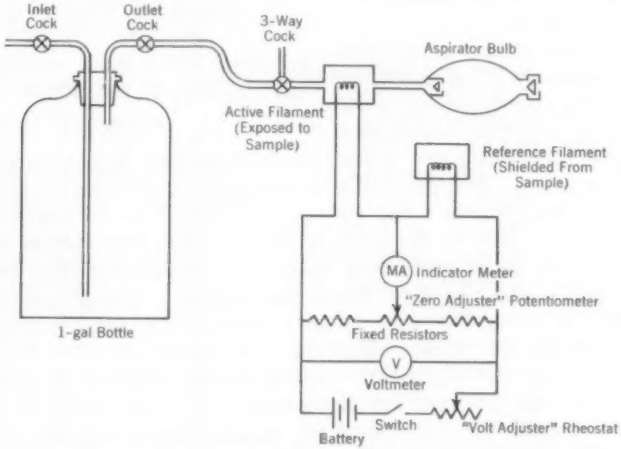

Fig. 1. Combustible Gas Indicator Circuit and Flow Diagram

3. Reagent

Solid sodium hydroxide pellets.

4. Procedure

4.1. If the approximate methane concentration of the water is unknown, it should be roughly determined as follows. Fill the gallon bottle about half full of water using a rubber tube con-

* The combustible gas indicator is also known by the following trade names: "Explosimeter," "Methane Gas Detector," and "Methane Tester," all manufactured by the Mine Safety Appliance Company, Pittsburgh, Pa.; "J-W Combustible Gas Indicator," manufactured by Johnson-Williams, Inc., Palo Alto, Calif.; and "Vapotester," manufactured by the Davis Emergency Equipment Company, Newark, N.J.

necting the sampling tap and the inlet tube, with the outlet tube open. With both the inlet and outlet tubes closed, shake the bottle vigorously for approximately 15 sec and allow the water to stand for approximately 1 min. Sample the gas phase by withdrawing gas from the outlet, leaving the inlet open to admit air. If the meter swings rapidly to a high level and then drops to zero, the methane-air mixture is too rich to burn, and a smaller volume of water should be taken for the final test; if the meter deflection is too small to read accurately, a larger volume of water should be taken.

4.2. If the water contains hydrogen sulfide, approximately 0.5 g of sodium hydroxide pellets may be added to the empty bottle to suppress interference from this gas. Evacuate the bottle using the filter pump. Fill the bottle not more than three-quarters full by connecting the inlet tube to the sampling cock, with the outlet tube closed. After the desired volume of water has been collected, allow the bottle to fill with air through the inlet tube. Close the inlet cock, shake the bottle vigorously for 60 sec, and let stand for at least 2 hr. Sample the gas phase through the outlet tube with the inlet cock open, taking the reading as rapidly as possible before the entering air has appreciably diluted the sample. Measure the volume of water sampled.

5. Calculation

The weight of methane (w), in milligrams, in the sample is given by the equation:

$$w = P\left(\frac{0.257\,V_g}{T} + \frac{890\,V_l}{H}\right)$$

where P is the partial pressure of methane in millimeters of mercury. T is the temperature in degrees Kelvin, V_g is the volume of the gas phase in milliliters, V_l is the volume of the liquid phase in milliliters, and H the Henry's Law constant in millimeters of mercury per mole of CH_4 per mole of water. The values for Henry's constant are given in Table 1. For most determinations, it may be assumed that atmospheric pressure is 760 mm and that the temperature is 20°C. The concentration of methane in the sample is then given by the equation:

$$\text{mg/l } CH_4 = R\left[6.7\left(\frac{V_0 - V_l}{V_l}\right) + 0.24\right]f$$

where R is the scale reading, V_0 the total volume of the sample bottle, V_l the volume of water sampled, and f the factor depending upon the instrument used. If the instrument reads directly in percentage of methane, $f = 1.00$. If the instrument reads in percentage of the lower explosive limit of methane, the factor would be 0.05. For instruments which require additional factors, the manufacturer should be consulted. For example, one commercial instru-

TABLE 1

Values for Henry's Constant

Temperature °C	Henry's Constant (H)
0	16.99×10^6
5	19.69×10^6
10	22.58×10^6
15	25.60×10^6
20	28.53×10^6
25	31.36×10^6
30	34.08×10^6
35	36.95×10^6
40	39.46×10^6
45	41.83×10^6
50	43.85×10^6
60	47.57×10^6
70	50.62×10^6
80	51.84×10^6
90	52.60×10^6
100	53.30×10^6

ment with a scale that reads in percentage of the lower explosive limit requires an additional factor of 0.77 for methane. Hence, the value of f in the above formula will be 0.77×0.05, or 0.0385.

For more accurate work, or in locations where the normal barometric pressure is significantly lower than 760 mm, the following equation should be used:

$$\text{mg/l } CH_4 = R\bar{P} \times \left[2.57 \left(\frac{V_0 - V_1}{TV_1}\right) + \frac{8{,}900}{H}\right] f$$

where T is the temperature in degrees Kelvin, $\bar{P}$ the barometic pressure in millimeters of mercury, and other symbols are the same as above.

6. Precision and Accuracy

The accuracy of the determination is limited by the accuracy of the instrument used, which is generally ± 10 per cent at midscale reading. The precision is ± 2 per cent at midscale reading, so that by frequent calibration of the instrument on known methane-air mixtures, the accuracy can be greatly improved.

B. Orsat Method

1. General Discussion

1.1. *Principle.* If methane is slowly mixed with oxygen in the presence of a platinum coil heated to yellow incandescence, most of the methane will be converted to carbon dioxide and water in a smooth reaction. Several subsequent passes of the mixed gases over the hot coil will serve to burn substantially all of the methane present in the sample. Oxygen must be removed from the original sample before the slow combustion is started; and the concentration of methane in the sample should not exceed 20 per cent, the remainder being an inert gas such as nitrogen.

Methane may also be converted to carbon dioxide and water in a catalytic oxidation assembly. If this procedure is used, an excess of oxygen is mixed with the sample prior to passage through the assembly.

1.2. *Interference.* Low-boiling hydrocarbons, other than ethane, and vapors from combustible oils could interfere in this analysis. These substances, however, are not likely to be present in water in sufficiently high concentration to affect the results significantly.

1.3. *Sensitivity.* This method will not be satisfactory for determining methane in water where the concentration is less than 2 mg/l.

1.4. *Sampling.* The sample may be collected in the same way that samples are collected for analysis by the combustible gas indicator method. The same precautions are necessary to obtain representative samples. The sodium hydroxide pellets may be omitted, and the sample bottle may be filled with water up to 90 per cent of its capacity.

2. Apparatus

Orsat type gas analysis apparatus, consisting of at least: [1] a water-jacketed gas buret with leveling bulb; [2] a carbon dioxide absorption pipet; [3] an oxygen absorption pipet; and [4] a slow-combustion pipet fitted with a safety glass plate, or catalytic oxidation assembly; and [5] a leveling bulb. If the slow-combustion pipet is used, a controlled source of current should be

available to heat the platinum filament electrically. The units should be placed in a rigid assembly and connected by a manifold of capillary glass tubing fitted with stop cocks to permit controlled communication between any of the units. Mercury is recommended as the confining liquid. Dilute solutions (1–5 per cent) of sulfuric acid containing 15–20 per cent sodium sulfate have also been used successfully. Any of the commercially available gas analyzers having these units may be used.

3. Reagents

3.1. *Potassium hydroxide solution.* Dissolve 500 g potassium hydroxide in distilled water and dilute to 1 liter.

3.2. *Alkaline pyrogallol.* Dissolve 30 g pyrogallic acid in water and make up to 100 ml. Add 500 ml of the potassium hydroxide solution.

3.3. *Oxygen gas.*

4. Procedure

4.1. Transfer 5–10 ml of the gas phase of the sample into the gas buret through a capillary tube connection to the sample bottle. Expel this portion of the sample to the atmosphere to purge the system. Select a sample which will result in a volume of approximately 60 ml at the step recorded as V_2 in the procedure. Transfer the sample to the buret, replacing it with water admitted through the inlet tube of the sample bottle. Bring the sample in the buret to atmospheric or reference pressure by adjusting the leveling bulb. Measure the volume accurately and record as V_1. Remove the carbon dioxide from the sample by three or four passes through the carbon dioxide absorption pipet charged with the potassium hydroxide solution. Before opening the stopcocks between the buret and any absorption pipet, make sure that the gas in the buret is under a slight positive pressure. This procedure will prevent the reagent in the pipet from contaminating the stopcock or manifold. Remove the oxygen by passing the sample through the oxygen absorption pipet charged with alkaline pyrogallol, until the volume of the sample remains constant. Measure the volume accurately and record as V_2. Store the sample in the carbon dioxide pipet.

4.2. Purge the inlet connections to the buret with oxygen by drawing 5–10 ml into the buret and expelling to the atmosphere. Transfer 35–40 ml of oxygen to the buret and measure accurately. Record this volume as V_3. Transfer the oxygen to the slow-combustion pipet and then transfer the sample from the carbon dioxide pipet to the buret. Heat the platinum coil in the combustion pipet to yellow heat, controlling the temperature by adjusting the current passing through the coil. Reduce the pressure of the oxygen in the pipet to somewhat less than atmospheric by means of the leveling bulb attached to the pipet. If a catalytic oxidation assembly is used, proceed directly to 4.4.

4.3. Pass the sample into the slow-combustion pipet at the rate of approximately 10 ml per minute. After the first pass, transfer the sample and oxygen mixture back and forth between the pipet and buret several times at a faster rate, allowing the mercury in the pipet to rise to a point just below the heated coil. Collect the sample in the combustion pipet, turn off the coil, and cool the pipet and sample with a jet of compressed air. Transfer the sample to the buret and measure its volume. Record as V_4.

4.4. If a catalytic oxidation assembly is used, 40 ml of oxygen is mixed with

not more than 60 ml of the stored gas sample, V_2. Pass the entire mixture through the assembly at a rate not greater than 30 ml per minute. After the first pass the mixture is transferred back and forth through the assembly between the buret and the reservoir at a rate not greater than 60 ml per minute until a constant residual volume is obtained. Record as V_4. During the usual three or four passes, the pressure should be maintained near atmospheric.

4.5. Determine the amount of carbon dioxide formed in the reaction by passing the sample through the carbon dioxide absorption pipet until the volume remains constant. Record the volume after this procedure as V_5.

4.6. A further check on the accuracy of the determination may be made by absorbing the residual oxygen from the sample. After this absorption, record the final volume as V_6.

5. Calculation

5.1. If methane is the only combustible gas present, the methane content of the sample will be given by any one of the following equations:

$$\frac{V_2 + V_3 - V_4}{2} = \text{volume of methane}$$

$$\frac{(V_2 + V_3 - V_4)100}{2V_1} = \% \text{ methane}$$

$$V_4 - V_5 = \text{volume of methane}$$

$$\frac{(V_4 - V_5)100}{V_1} = \% \text{ methane}$$

$$\frac{V_3 - V_5 + V_6}{2} = \text{volume of methane}$$

$$\frac{(V_3 - V_5 + V_6)100}{2V_1} = \% \text{ methane}$$

Results from these calculations should be in reasonable agreement. If they are not, ethane may be present. For methane and ethane together the following equations apply:

$$\frac{4(V_2 + V_3) - 9V_4 - 5V_5}{3} = \text{volume of methane}$$

$$\frac{[4(V_2 + V_3) - 9V_4 - 5V_5]100}{3V_1} = \% \text{ methane}$$

$$\frac{2(3V_4 - 2V_5 - V_2 - V_3)}{3} = \text{volume of ethane}$$

$$\frac{2(3V_4 - 2V_5 - V_2 - V_3)100}{3V_1} = \% \text{ ethane}$$

Each volume of methane will react with 2 volumes of oxygen and each volume of ethane will use 3.5 volumes of oxygen. This relationship may be used as a check on the accuracy of the analysis.

$$2 \times \text{volume of methane} + 3.5 \times \text{volume of ethane} = V_3 - (V_5 - V_6)$$

or, if volumes are not calculated:

$$V_2 + 3V_4 - V_5 = 2V_3 + 3V_6$$

If agreement is not obtained, the analysis should be repeated after the apparatus has been thoroughly checked for sources of error, such as leaky stopcocks or connections. The possibility that the sample contains other combustible gases, such as propane or butane, should be considered.

5.2. The percentage of methane given by this analysis may be used in applying Henry's Law to obtain the

concentration of methane in the original water sample. This calculation is given in the Combustible Gas Indicator Method for methane in water (see p. 1080). The percentage of methane as determined by this analysis should be substituted for R (scale reading) in the calculation, and the factor f will be 1.

6. Precision and Accuracy

A gas buret can measure gas volume with a precision of 0.05 ml and a probable accuracy of 0.1 ml. With methane (gas phase) concentrations larger than 2 per cent, the overall error of the gas determination can be made less than ± 5 per cent.

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Mixed Bed Ion Exchange for the Removal of Radioactivity

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A paper (No. 173) presented on Dec. 16, 1955, under the sponsorship of AWWA, at the Engineers Joint Council's Nuclear Eng. and Science Congress, Cleveland, Ohio, and revised in February 1957 by H. Gladys Swope, Sr. Chemist, Chem. Eng. Div., Argonne National Laboratory, Lemont, Ill.

THE main theme of this article has several facets. These may be summarized, however, as the removal of radioactivity by mixed bed ion exchange.

During experiments devoted principally to a study of the removal of mixed fission products from water by the utilization of ion exchange, many questions were raised including: the size of ion-exchange units; the flow rate; the effect of radioactivity on the capacity of the units; the use of cation resin alone or the need for a mixed bed; the decontamination factors possible with such units; and the discarding of the resins at exhaustion rather than their regeneration.

Because of these questions and the present upsurge in the building of reactors by industry, it has seemed fitting to cover the removal of radioactivity by mixed bed ion exchange in a general way and to try to answer the questions received from time to time, as the literature on this subject is very meager.

The first article to appear in the literature on the removal of radioactivity by mixed bed ion exchange was by Ayres (*1*) who used laboratory wastes to which he added 1.5×10^6 mixed fission product activity and poured these through a mixed resin.* The waste was 0.015*N* in acidity and contained 3,000 ppm total solids. A decontamination factor † of 10^6 was obtained for a throughput equivalent to 59 gal per cubic foot of mixed resin. Breakthrough was taken as the first appearance of activity in the effluent.

Lauderdale and Emmons (*2*) investigated the removal of mixed fission products from tap water using mixed bed ion exchange in conjunction with another bed filled with steel wool, clay, and activated carbon. They were able to pass the equivalent of 119 gal of water per cubic foot of mixed resin before the breakthrough point of 10 counts per minute per milliliter (cpm per milliliter) was reached. The Oak Ridge tap water contained 200 ppm total solids, and the pH of feed was adjusted to 7.5 with sodium hydroxide.

Balcar and associates (*3*) studied removal of 1.5×10^3 cpm per milliliter mixed fission products added to Jersey City tap water, using as their breakthrough point 20 cpm per milliliter activity in the effluent. The throughput volumes varied between 230–295 gal per cubic foot of resin depending on the resins used. Jersey City tap water contained 90 ppm total solids. The same authors also studied the removal of Cs^{137}, Sr^{90}, Co^{60}, Ni^{63}, Ru^{106}, Ce^{144}, S^{35},

* The mixed resin was Amberlite XE-81, a product of Rohm & Haas Company, Philadelphia, Pa.

† The decontamination factor is the amount of radioactivity in the feed divided by the amount of radioactivity in the effluent.

and C^{14} from various salt solutions containing 1,000 and 5,000 ppm total solids.

Tap Water Radioactivity Removal

Intensive investigations have been made by the waste processing group at the Argonne National Laboratory on the use of mixed bed ion exchange for the removal of mixed fission products from tap water.

The three main objects of these investigations were: [1] to see what the optimum conditions were for the removal of radioactivity; [2] to discover the capacity of the resins under these conditions; and [3] to find the most economical use of regenerant solutions.

The feed used was tap water to which 1- to 2-year old mixed fission products were added. This tap water contained 300 ppm total solids, 85 ppm total hardness as $CaCO_3$, and had a pH of 9.0–9.5.

Laboratory experiments using a 1½-in. column containing 45 cu in. of mixed resin (30 cu in. of anion resin * and 15 cu in. of cation resin †) indicated that an overall decontamination factor of 10^4 was obtained with neutral tap water which contained 10^5 cpm per milliliter ‡ of gross beta-gamma activity. The volume processed was equivalent to 440 gal per cubic foot of the mixed resin. When a 3:1 ratio of anion to cation resin was used, the capacity of the bed was increased to 630 gal per cubic foot (*4*).

The breakthrough point was the point at which the effluent had a resistivity of 200,000 ohms.

The question has often been asked as to whether it would be practical to use a mixed bed column in the same manner as a roughing filter—that is, to remove gross contamination—followed with either a second mixed bed or a cation-exchange column alone for polishing the effluent. The results of such experiments are given in Table 1. A 1½-in. diameter column which contained 46 cu in. of mixed resin was used as the primary column. The effluent from this column was then split three ways: one third passing through a small mixed bed column containing a 2:1 ratio of anion to cation resin; one third through a mixed bed having a 1:2 ratio of anion to cation; and the third portion passing through the cation resin only.

Until breakthrough of total solids the primary column gave an overall decontamination factor of 1.4×10^4 in the first cycle, whereas the two secondary mixed bed columns gave an overall decontamination factor of 1.2 and 1.9 $\times 10^5$, respectively. The cation column showed an overall decontamination factor, including the primary mixed bed, of 2.3×10^4.

Capacity for Radioactivity Removal

In order to determine the effect of continued reuse of a mixed bed resin for removal of radioactivity, a column

* A strongly basic anion exchanger made from styrene and divinylbenzene containing quaternary ammonium groups, marketed as Nalcite SAR by the National Aluminate Corporation, Chicago, Ill., and as Dowex 2 by the Dow Chemical Company, Midland, Mich. Unless otherwise indicated hereafter, the term "anion resin" will refer to the hydroxyl form (Nalcite SAR-OH^-).

† A cation exchanger made from styrene and divinylbenzene containing sulfonic acid groups, marketed as Nalcite HCR by the National Aluminate Corporation, Chicago, Ill., and as Dowex 50 by the Dow Chemical Company, Midland, Mich. Unless otherwise indicated hereafter, the term "cation resin" will refer to the hydrogen form (Nalcite HCR-H^+).

‡ Measured by a Nuclear Measurements Corp. proportional counter having 62 per cent counting yield.

of larger diameter was required to regenerate the resins effectively. Two 4-in. diameter, 52-in. high lucite columns (Fig. 1) were constructed, into which were measured 1,550 ml of cation resin and 3,200 ml of anion resin equivalent to 0.168 cu ft of mixed resin. In one column the feed was

cause most of the radioactive nuclides would be in the ionic form at the lower pH, whereas some, such as zirconium would be colloidal at pH 7.0. A^- the anion resin broke through first, probably because of the nitrate ion from nitric acid used to reduce the pH to 2.5, it is recommended that a 3:1 ratio of

TABLE 1

Removal of Mixed Fission Product Activity From Neutral Tap Water by a Mixed Bed Ion Exchanger

Incremental Feed Volume—*l*		Average Activity—*cpm/ml*					Decontamination Factor			
Through Primary Column*	Through Secondary Column†	Feed‡	Primary Column Effluent	Effluent Through Secondary Column With Anion-Cation Resin Ratio of: 2:1	1:2	Cation Only	Through Primary Mixed Bed	Overall Through Secondary Column With Anion-Cation Resin Ratio of: 2:1	1:2	Cation Only
First Cycle										
2.7	0.9	1.1×10^5	67	1.5	0.8	13.0	1,600	7.3×10^6	1.4×10^5	8,500
9.9	3.3	1.5×10^5	7	2.0	1.0	4.2	2.0×10^4	7.5×10^6	1.5×10^5	3.6×10^6
27.2	9.1	2.0×10^5	2	1.2	0.9	3.4	1.0×10^5	1.7×10^6	2.2×10^5	5.9×10^6
3.0	1.0	2.6×10^5	39	1.0	1.0	31.0	6,600	2.6×10^5	2.6×10^5	8,400
1.2	0.4	2.6×10^5	103	0	0	56.0	2,500	$>10^6$	$>10^6$	4,600
44.0	14.7						1.4×10^4§	1.2×10^5§	1.9×10^5§	2.3×10^4§
Second Cycle (After First Regeneration of Primary Bed)										
4.0	1.0	2.3×10^5	460	1.2	2.5	49.0	500	1.9×10^6	9.2×10^6	4,600
5.0	1.5	1.7×10^5	270	3.7	3.1	8.0	630	4.6×10^6	5.5×10^6	2.1×10^6
5.0	1.0	1.9×10^5	78	2.0	8.0	6.0	2,400	9.5×10^6	2.4×10^6	3.2×10^6
18.0	6.0	2.4×10^5	22	4.0	2.8	7.3	1.1×10^4	6.0×10^6	8.6×10^6	3.2×10^6
10.0	3.0	2.8×10^5	8	2.3	4.0	15.0	3.5×10^4	1.2×10^5	7.0×10^6	1.9×10^6
1.0	1.0	2.8×10^5	78	2.5	5.5	29.0	3,600	1.1×10^5	5.1×10^6	1.0×10^6
43.0	13.5						2,500‡‡	6.2×10^4‡‡	5.1×10^4‡‡	1.7×10^4‡‡

* Primary column was 1½ in. in diameter with a bed height of 22 in. and contained 45.8 cu in. of mixed resins.
† The three secondary columns were ½ in. in diameter with a bed height of 14.5 in. and contained 3 cu in. of resins.
‡ The tap water contained approximately 10^5 cpm per milliliter mixed fission product activity from Hanford dissolver solution, pH 7.0.
§ Integrated decontamination factor.

tap water adjusted to pH 7.0 and, in the other, it was adjusted to pH 2.5. Typical results are shown in Table 2. It is interesting to note that twice as much capacity was obtained at pH 7 as was obtained at pH 2.5. The decontamination factors, however, are not as great as at pH 2.5, undoubtedly because most of the radioactive nuclides would be in the ionic form at the lower pH, whereas some, such as zirconium would be colloidal at pH 7.0. A^- the anion resin broke through first, probably because of the nitrate ion from nitric acid used to reduce the pH to 2.5, it is recommended that a 3:1 ratio of anion to cation resin be used in order to increase the capacity of the mixed bed.

Method of Regeneration

On the basis of the above capacity for water containing 300 ppm of total solids it can be seen that it would be uneco-

nomical to process only 400–800 gal per cubic foot of mixed resins if regeneration were not practiced—unless, of course, the resins required remote handling because of curie level activity. Regenerating solutions would be radioactive and would require further processing, so it is essential that these solutions be kept to a minimum volume. Two processes seemed feasible: a two-step process, or the simultaneous method of regeneration. In both processes the resins were separated by backwashing, but instead of using clean rinse water for this purpose, the water on top of the resin was recirculated so as to use only a small additional amount of water. In the two-step process a 4 per cent caustic solution was passed through the entire resin column, thus changing the anion resin to the hydroxyl form and the cation resin to the sodium form. The liquid in the column was drained to the cation-anion interface and 6 *N* nitric acid was run onto the cation resin by means of a tube. Several distilled-water rinses followed, in each case using a minimum volume. Instead of rinsing until a pH of 6–7 was obtained, rinsing was discontinued when the effluent had a pH of 3–4. The results of laboratory experiments are shown in Table 3, and a schematic drawing of the apparatus is shown in Fig. 2.

TABLE 2

*Experimental Mixed Bed Columns**

Run No.	Feed† pH	Volume *gal/cu ft*	Final Effluent Fraction *cpm/ml*	Integrated Decontamination Factor
H-20D	7.0	707	13	8.7×10^3
H-30D	7.0	707	10	1.5×10^4
H-32D	7.0	628	7	3.4×10^4
H-35C	7.0	628	7	1.4×10^4
H-26D	2.5	393	10	2.0×10^4
H-36D	2.5	314	0	1.0×10^5
H-38D	2.5	414	41	4.0×10^4
H-40D	2.5	393	17	2.8×10^4

* Columns were made of lucite 4 in. in diameter and contained 0.168 cu ft of mixed anion and cation resin in a 2:1 ratio. The flow rate of the feed was 2 gpm per cubic foot.

† Feed was tap water to which was added 1.2×10^5 cpm per milliliter beta-gamma activity from 2-year old mixed fission products.

In the simultaneous method of regeneration, after the resins are classified by the method just mentioned, the caustic is passed down through the anion column, 6 *N* nitric acid is passed upflow through the cation column, and both are removed at the interface (Fig. 3). As the volume of 4 per cent caustic was 9 l for the 0.168 cu ft of mixed resins, and as only 1 l of 6 *N* nitric acid was required, 8 l of caustic were passed through the column before any nitric acid was added. The equipment manufacturers recommended that water be passed upflow through the cation bed until it was time to add the nitric acid, but experimental work indicated that this was unnecessary. Again the object was to keep the regenerant solutions to a minimum. In all of these preliminary tests employing the simultaneous method of regeneration, the capacity of the resins was not impaired by these procedures when the experiments were run with inactive solutions.

When using tap water to which radioactivity had been added, it was found that continuous cycles at pH 7 showed some erratic results. Further investigation indicated that in order to obtain good removal of radioactivity when the feed was at pH 7 it was advisable to add a so-called decontaminating step. This was accomplished by passing 6 *N* nitric acid, before regeneration, downflow through the column at the rate of 0.4 gpm per cubic foot. The amount used was equal to that required to cover the resin bed. When

the feed is at pH 2.5 this decontaminating step is required only after every fourth or fifth cycle. The extra step also adds to regenerant volume, and it is therefore recommended that the mixed bed be regenerated in the usual manner until a marked decrease of capacity for activity removal appears and, at this time, to employ the decontaminating step. It might also be possible to use less concentrated nitric acid for this particular step although 6 *N* nitric was found to be optimum for regenerating the cation resin (*5*).

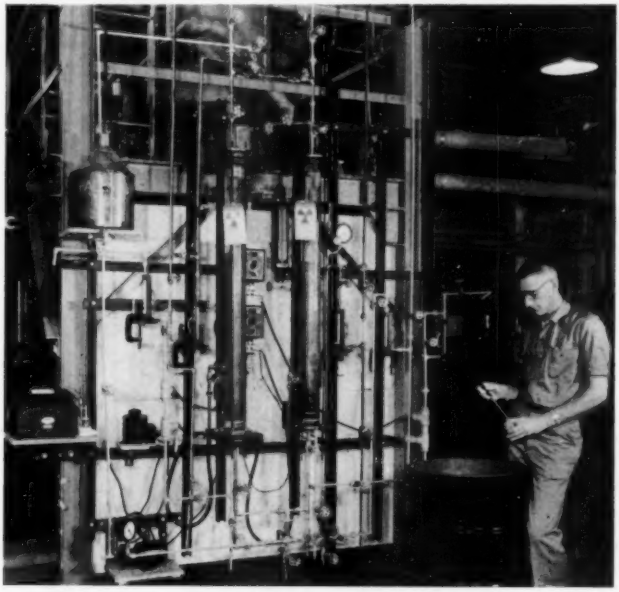

Fig. 1. Pilot Plant Mixed Bed Ion-Exchange Columns

Efficiency of Regeneration

In a series of ten laboratory experiments using the two-step regeneration process and neutral tap water containing 10^5 cpm per milliliter mixed fission product activity as feed, the average regeneration efficiency was 70 per cent (*6*). The formula for calculating percentage regeneration efficiency is:

$$\text{Regeneration efficiency} = \frac{\text{Capacity after regeneration}}{\text{Determined initial capacity}} \times 100$$

In another series of ten experiments using the small 4-in. diameter pilot plant columns, considerably better results were obtained by the simultaneous method of regeneration. The new resin bed processed 650 gal of tap water per cubic foot of mixed resins prior to total solids breakthrough. Six cycles using the two-step process showed capacities of 321, 262, 298, 220, 494, and 619 gal per cubic foot, or an average of 57 per cent efficiency. Subsequent cycles using the simultaneous method showed

capacities of 821, 792, 750, and 780 gal per cubic foot, or an efficiency of 121 per cent.

work (*7*) has shown that flow rates as high as 10 gpm per cubic foot do not impair the capacity of a cation ex-

TABLE 3

*Regeneration of Primary Mixed Bed Ion-Exchange Column**

Solution	Volume		Anion or Cation Regenerant Flow Rate	Regenerant Effluent	
	ml	*gal/cu ft*	*gal/cfm*	pH	*cpm/ml*
First Regeneration					
Distilled water for backwashing	750	7.5		1.2	1.1×10^4
4 per cent sodium hydroxide (anion regenerant)	800	8	1.0	2.5	2.4×10^5
Water rinse	500	5		1.2	8.8×10^4
6 *N* nitric acid (cation regenerant)	170	1.7	0.4	<1	4.0×10^7
First water rinse	1,000	10		0.3	1.4×10^6
Second water rinse	500	5		2.2	6×10^3
Third water rinse	500	5		3.3	8×10^2
Fourth water rinse	500	5		3.5	5.2×10^2
Fifth water rinse	500	5		7.2	19
	5,220	52.2			
Second Regeneration					
Backwash†	750	7.5		1.9	8.1×10^4
4 per cent sodium hydroxide (anion regenerant)	1,375	13.75	1.0	11.4	9.2×10^4
Distilled water rinse	500	5.0	1.0	11.8	8.2×10^4
6 *N* nitric acid (cation regenerant)	170	1.7	0.4	0.7	4.5×10^6
First water rinse	500	5.0	2.0	0.3	4.0×10^6
Second water rinse	500	5.0		1.2	2.9×10^4
Third water rinse	500	5.0		2.8	2.0×10^3
Fourth water rinse	500	5.0		4.0	246
Fifth water rinse	500	5.0		4.5	56
	5,295	52.95			

* Total volume of resin was 45.3 cu in.
† Feed remaining in column from absorption cycle.

Effect of Flow Rate

The manufacturer's recommendation for rate of flow through a mixed bed ion-exchange unit is 2 gpm per cubic foot. This same recommendation is given for a cation exchanger, but some

changer for radioactivity removal. With a mixed bed exchanger (*8*), however, the capacity was greater at the 2-gpm per cubic foot rate (340 compared to 280 gal per cubic foot), and the integrated decontamination factors

were approximately 2 to 5 times greater at the 2-gpm than at the 5-gpm per cubic foot rate. In these experiments tap water adjusted to pH 2.5 was used, and 10^5 cpm per milliliter mixed fission products were added. It is therefore concluded that, for the best removal of radioactivity by mixed bed ion exchange, the flow rate should not exceed the 2-gpm per cubic foot rate, and a lower rate might be even more desirable.

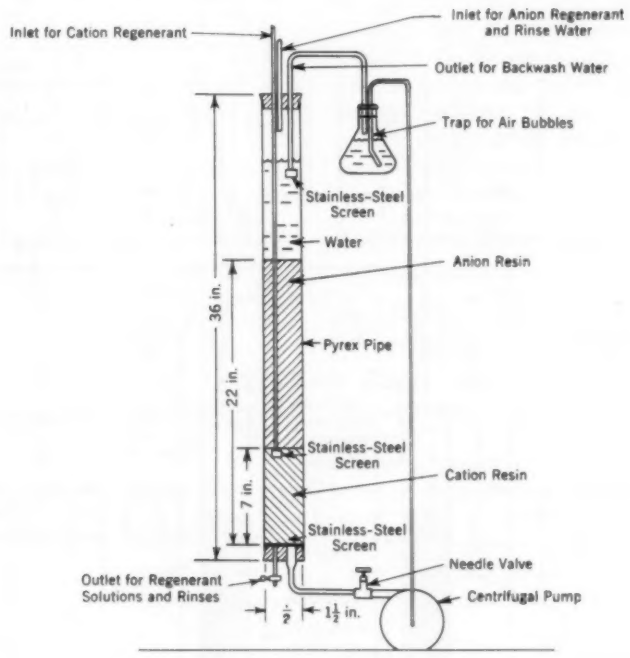

Fig. 2. Mixed Bed Regeneration Apparatus

The centrifugal pump is powered by a $\frac{1}{30}$-hp motor

pH, Resistance, and Activity

Laboratory wastes from ion-exchange experiments which contained Na, Ca, Fe^{+++}, and Al nitrates equivalent to about 300 ppm calcium carbonate and activity ranging from 0.1 to 2,200 cpm per milliliter, mainly cesium 137, with some mixed fission product activity was passed through a mixed bed column. The column was 2 in. in diameter and contained 0.014 cu ft cation resin and 0.028 cu ft anion resin. During this run, pH, resistivity, and activity of the effluent were noted by analyzing a composite effluent after a day's operation. A correlation was noted among these variables at the point of the exhaustion of the resin column for activity. Breakthrough point was taken as 5 cpm per milliliter in the effluent; at this point the resistance was at the low point and the pH dropped from 6.8 to

3.5. It is noted that immediately following this, the activity level rose vertically. The results are shown in Fig. 4.

Mixed and Dual Beds

As it is easier to regenerate a dual bed than a mixed bed, a study was made of the capacity and decontamination obtained using the two. For the dual bed, 3 cu in. cation resin was used in series with 6 cu in. anion resin. The same amounts of resins were used in the mixed bed. The feed was neutral tap water to which was added 2.5×10^5 cpm per milliliter mixed fission products.

Until breakthrough of total solids, the decontamination factor for the two-

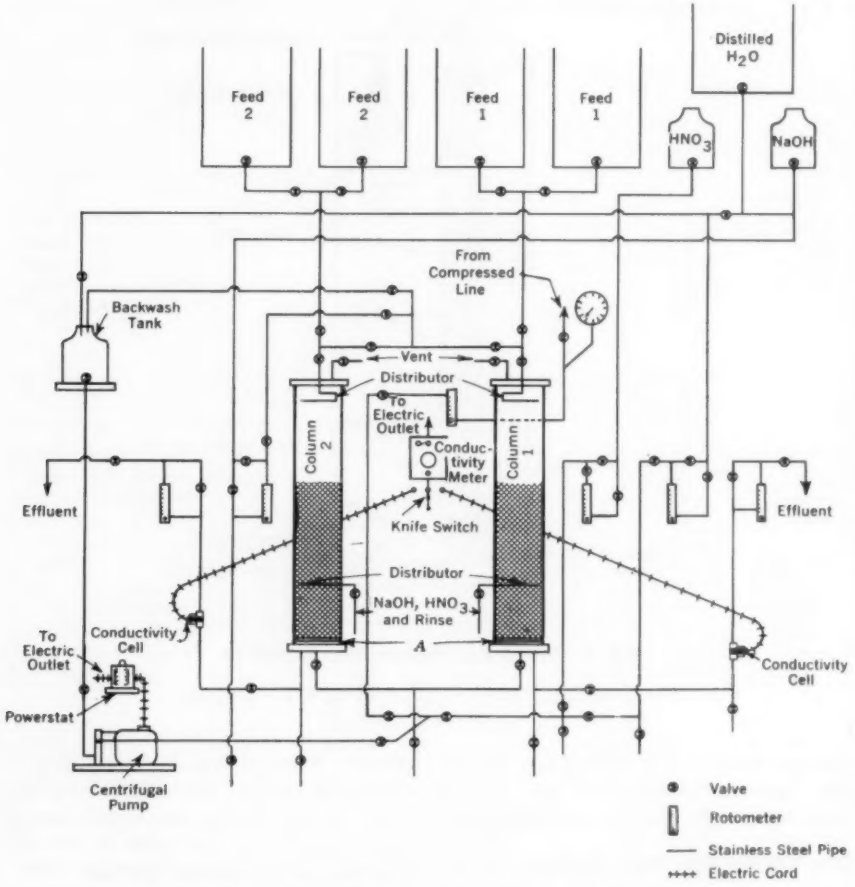

Fig. 3. Pilot Plant Mixed Bed Ion-Exchange Unit Piping Diagram

Columns 1 and 2 are made of lucite, 4-in. OD, 52½ in. long. The parts labeled A *are stainless-steel screens and discs made of tetrafluoroethylene polymer plastic.*

bed system was 1.4×10^3 and for the mixed bed, 1.7×10^4 with capacities of 406 and 356 gal per cubic foot, respectively.

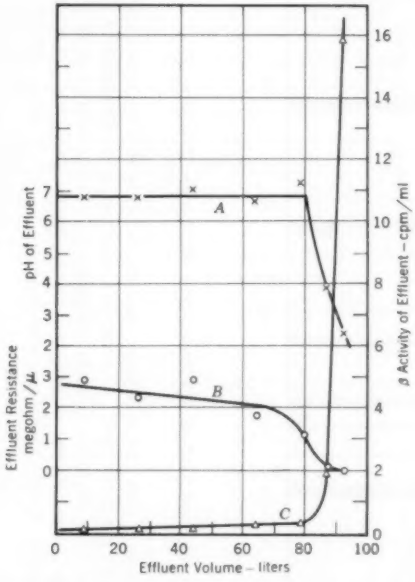

Fig. 4. Variation in pH and Resistance Compared to Activity of Effluent From Mixed Bed Ion Exchanger

Curve A *represents* pH; *Curve* B, *resistance; and Curve* C, *beta activity.*

If decontamination factors of only 50 are required, however, an additional 550 gal per cubic foot of resin can be passed through the two-bed system before regeneration is required. With the mixed bed, a decontamination factor of 140 can be obtained with the passage of 610 gal per cubic foot beyond total solids breakthrough before regeneration is required. These data indicate that there is not much difference in total capacity of the resins whether a two-bed or mixed bed system is used, but decontamination factors are approximately 3–10 times greater with the mixed bed system. These data are shown in Table 4.

Cation and Mixed Bed

The amount of radioactivity removed by a cation bed is as different from that removed by a mixed bed as is softened water from demineralized water. From a purely chemical point of view, it would appear that, as most radioactive ions are cations, it would be logical to expect a cation exchanger to give almost as good decontamination as a dual or mixed bed system. A cation bed, however, does not give a decontamination factor better than 10–15 unless the only ions present are radioactive ones—

TABLE 4

*Comparison of Dual and Mixed Bed Ion Exchangers for Removal of Radioactivity**

Stage of Experiment	Volume Increment gal/cu ft		Cumulative Volume gal/cu ft		Integrated Decontamination Factors	
	Dual Bed	Mixed Bed	Dual Bed	Mixed Bed	Dual Bed	Mixed Bed
Before total solids breakthrough	406	356	406	356	1.4×10^3	1.7×10^4
After total solids breakthrough	559	610	965	966	44.0	1.4×10^3
	203	203	1,168	1,169	3.7	15.0
	127	127	1,295	1,296	4.0	3.4

* Columns used were ¾ in. in diameter containing 3 cu in. cation and 6 cu in. anion resin. The feed was neutral tap water to which was added 2.5×10^5 mixed fission products flowing at a rate of 2 gpm per cubic foot.

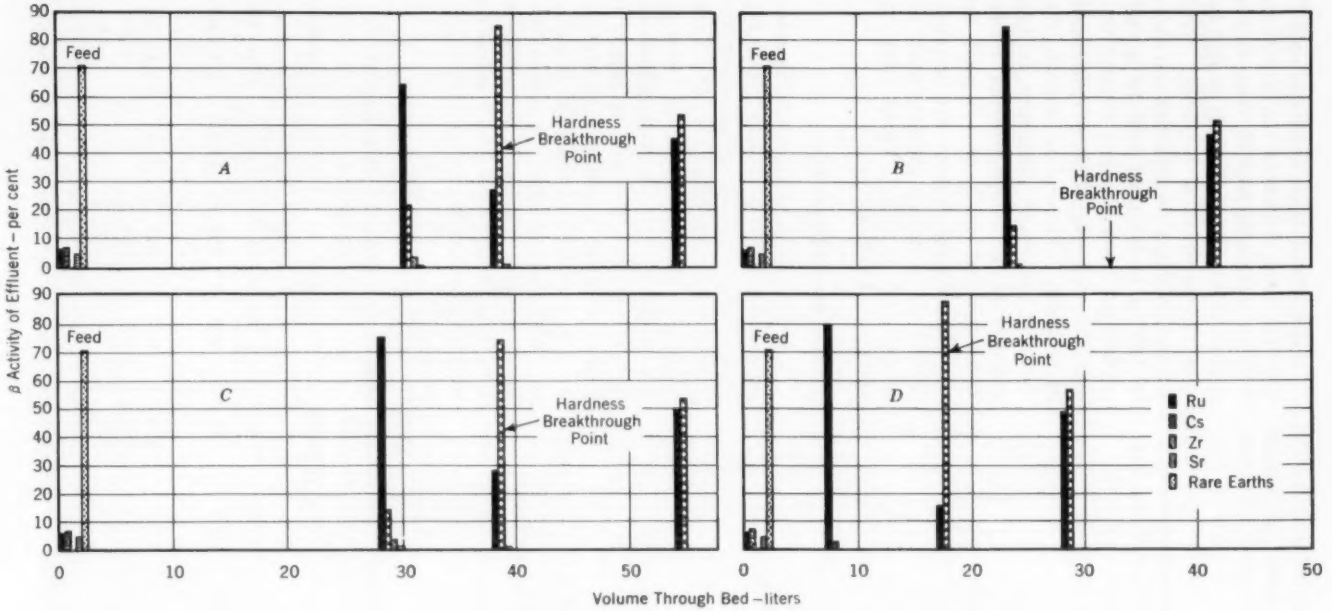

Fig. 5. Fission Product Distribution in Feed and in Effluent From Exchange Columns

The feed was tap water adjusted to pH 2.5 with nitric acid, 2-year-old dissolver solution being added to attain an activity level of 3.5×10^5 cpm per milliliter; the rate of flow was 2 gpm per cubic foot. The resins used were: in Experiment A *(top left), a 3-cu in. column of hydrogen form cation; in Experiment* B *(top right), a 3-cu in. column of regenerated hydrogen form cation; in Experiment* C *(bottom left), a 3-cu in. column of sodium form cation; in Experiment* D *(bottom right), a 1.5-cu in. hydrogen form cation and a 3-cu in. hydroxyl form anion mixture.*

still several orders of magnitude under mixed bed results.

It should be noted from Table 1 that the decontamination obtained by the use of a cation resin only on the effluent from a mixed bed resin was considerably less than when the same effluent was passed through a second mixed bed column.

In order to compare the specificity of various ion-exchange materials, a group of four laboratory columns was set up old mixed fission product solution to provide about 3×10^5 beta cpm per milliliter. Samples of the effluent were taken at frequent intervals, and pH, total hardness, and alpha and beta activity determined. One effluent sample was analyzed for fission product distribution before hardness breakthrough, one at hardness breakthrough, and one after breakthrough.

All of the cation columns contained 3 cu in. of resin and the mixed bed 1.5

TABLE 5

*Comparison of Cation and Mixed Bed Resins for Removing Alpha and Beta Activity From Tap Water**

Type of Resin	Volume of Resin *cu in.*	Hardness Breakthrough Volume *l*	Fractions	Throughput Volume—*l*		Activity† *cpm/ml*		Decontamination Factor		Integrated Decontamination Factor	
				Increment	Total	α	β	α	β	α	β
—		—	Feed	—	—	290.0	3.5×10^5	—	—	—	—
Cation H^+	3	38	1–10	30	30	7.0	1.5×10^4	41	23	—	—
			11–13	8	38	12.0	5.8×10^4	24	6	36	14.6
			14–32	16	54	31.0	8.8×10^4	9	4	—	—
			33–40	32	86	19.0	4.9×10^4	15	7	17	7.8
Cation Na^+	3	38	1–9	28	28	12.0	1.5×10^4	24	23	—	—
			10–13	10	38	20.0	3.9×10^4	15	9	21	16.0
			14–35	16	54	29.0	1.0×10^5	10	3	—	—
			36–43	32	86	23.0	5.1×10^4	13	7	15	7.5
Regenerated Cation H^+	3	30–34	1–8	23	23	2.8	1.2×10^4	104	29	—	—
					30	—	—	—	—	85	17.5
			9–18	18	41	14.0	7.3×10^4	21	5	—	—
			19–30	45	86	21.0	5.1×10^4	14	7	19	7.8
Mixed bed Cation H^+ and Anion OH^-)	4.5	4‡ 12	1–3	4	4	0	46	—	—	>290	7.4×10^3
			1–4	1	5	0	192	>290	1,800	—	—
			6–11	12	17	1.7	1.9×10^4	171	18	242	27.0
			12–22	11	28	6.7	7.1×10^4	43	5	—	—
			23–31	17	45	4.8	4.2×10^4	60	8	74	9.2

* pH of feed was 2.5.
† Proportional counter (62 per cent yield for beta, 50 per cent for alpha), weighted average activity over range shown.
‡ Total solids breakthrough.

to use the same feed. The columns contained cation resins in the hydrogen and sodium forms, a regenerated batch of the hydrogen form of this resin, and a mixed bed composed of a 2:1 ratio of anion to cation resin in the hydroxyl and hydrogen forms, respectively. The feed was tap water adjusted to pH 2.5 to which was added sufficient 2-year

cu in. of hydrogen form cation and 3.0 cu in. of hydroxyl form anion resin. The volume passed through the cation columns was 86 l. Total hardness broke through with both the sodium and hydrogen forms of the cation resin at 38 l and between 30–34 l with the regenerated resin. The integrated decontamination factor at hardness break-

through was between 21 and 85 for alpha, and from 15 to 18 for beta. The overall integrated decontamination factors varied between 15 and 19 for alpha, and between 7.5 and 7.8 for beta.

With the mixed bed column, decontamination factors of 290 and 7.4×10^3 for alpha and beta activity, respectively, were obtained prior to the total solids breakthrough point which corresponded to about 4 l of effluent. For this column, which contained only half as much cation resin as the columns containing cation resin alone, hardness broke through at 12 l. After total solids broke through, the activity in the effluent increased markedly. These data are shown in Table 5.

TABLE 6

*Integrated Decontamination Factors Obtained on a Mixed Bed Ion Exchanger Using a Low-Solids Water**

Fraction Numbers	Σ Volume		Integrated Decontamination Factors							
			α Activity				β-γ Activity			
			Regenerated Used Resin		New Resin		Regenerated Used Resin		New Resin	
	l	*gal/cu ft*	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2	Run 1	Run 2
1–8	250	392	3.6×10^3	2.0×10^3	6.0×10^3	1.4×10^3	6.8×10^3	7.1×10^3	5.9×10^4	1.7×10^4
1–9	300	471	2.9×10^3	1.5×10^3	6.0×10^2	1.8×10^3	7.6×10^3	8.3×10^3	5.9×10^4	1.6×10^4
1–10	350	550	3.5×10^3	528	1.2×10^4	1.9×10^3	8.0×10^3	9.1×10^3	3.8×10^4	1.5×10^4
1–11	400	628	3.5×10^3	625	3.0×10^3	1.9×10^3	8.6×10^3	8.3×10^3	4.2×10^4	1.5×10^4
1–12	450	707	2.8×10^3	691	2.4×10^3	1.9×10^3	9.2×10^3	9.1×10^3	4.5×10^4	1.5×10^4
1–13	500	786	2.3×10^3	760	2.2×10^3	1.9×10^3	1.0×10^4	1.0×10^4	4.2×10^4	1.5×10^4
1–14	550	864	2.7×10^3	866	1.8×10^3	1.6×10^3	1.1×10^4	1.1×10^4	4.2×10^4	1.5×10^4

* The columns were 4 in. in diameter and contained 0.168 cu ft of mixed resins (2:1 ratio of anion to cation resin). The feed was distilled water adjusted to pH 7.0 with 4*M* NaOH "spiked" with $\sim 10^5$ cpm per milliliter fission product activity. The rate of flow was 2 gpm per cubic foot.

Activity Distribution in Effluents

The distribution is shown in Fig. 5. The effluent activity discharged from exhausted cation resin columns of all three types was mainly ruthenium and cesium. Cesium was retained fairly well on the column until hardness breakthrough, at which time cesium broke through and from this point was being eluted. Ruthenium was only partly retained on the columns throughout these experiments. A more thorough discussion of the work with cation resin columns was reported by Swope and Anderson (*7*). The behavior of the mixed bed column was similar, except that very little activity broke through prior to total solids breakthrough, but, after this point was reached, ruthenium was the first element to elute followed by a small amount of cesium.

Very-Low-Solids Water

Reactor engineering groups have indicated an interest in the removal of mixed fission product activity by mixed bed exchangers from low solids content water at or near neutrality. Distilled water (final solids content approximately 20 ppm) containing approximately 10^5 cpm per milliliter beta-gamma activity (62 per cent counting yield) and 100 cpm per milliliter alpha activity (50 per cent counting yield)

from mixed fission products was passed through two mixed bed columns in parallel. One of the columns had previously been used for removing activity from tap water and had subsequently been regenerated. The other contained new resin which had been "conditioned" twice, first by exhausting it with tap water and then by regenerating it. On duplicate runs, within the experimental errors, all alpha activity was removed and integrated decontamination factors of from 10^4 to 4×10^4 were obtained for beta-gamma activity after the passage of 864 gal per cubic foot of mixed resin. These data are shown in Table 6.

As it has been demonstrated, at least with water containing up to 10^5 cpm per milliliter of old mixed fission product activity, that the activity will elute at the total solids breakthrough point, one can estimate the capacity of a mixed bed exchanger for removing radioactivity. In the preceding example the column was shut down arbitrarily after the passage of 550 l, or the equivalent of 864 gal per cubic foot of resin. This would have been past the breakthrough point if laboratory tap water had been used, but the run was stopped because it would have taken too long to exhaust the resin using water containing only 20 ppm total solids.

TABLE 7

Demineralization of Gamma Irradiation Canal Water

Run No.	Throughput Volume		Pool Water			Effluent		
	At Breakthrough* *gal*	At End of Run *gal*	pH Range	Total Solids *ppm*	β-γ Activity *cpm/ml*	pH At End of Run	β-γ Activity *cpm/ml*	
							At Breakthrough	At End of Run
P-1	5,000	9,100	8.0	~550.0	6,400	10.8	0	59.0
P-2	7,200	9,100	8.9	406.0	6,000	5.6	1.4	158.0
P-3	7,100	8,320	9.0	350.0	6,000	4.7	1.0	0
P-4	7,500	7,900	8.5	348.0	5,500	4.5	0.5	1.4
P-5	~9,000†	10,050	8.6	270.0	4,900	4.9	0	1.4
P-6	~11,000†	11,600	8.5	225.0	5,400	5.6	1.0	0.9
P-7	~17,000†	19,500	8.0	95.0	2,800	5.1	1.0	2.0
P-8	32,610	38,300	7.8–7.5	80.0	1,200	5.5	0.4	0.4
P-9	114,570	114,570	7.6–6.8	33.0–10.0	905–230	6.0	0.8	0.8
P-10	48,500	48,500	6.8–7.6	12.0–6.0‖	360–310	5.7	0.3	0.3
P-11	554,250	554,250	7.7–6.9	6.0–21.0#	300– 50	5.5	0.6	0.6
P-12	676,700	676,700	6.5–7.3	2.0–0	64– 18	6.4	0.2	0.2
P-13	2,230,000	2,230,000	7.5–6.6	0.2	64– 23	6.4	0	0.0
P-14	269,800‡	269,800	7.4–7.6	—	93– 25	6.3	0	0.0
P-15	414,400§	437,000	7.5–6.4	—	62– 20	6.3	0.1	0.3
P-16	1,443,000	1,450,000	6.2–7.6	0.07	7–101	5.8	0.5	0

* Breakthrough is the point where the effluent conductivity is 1×10^6 ohm-cm.
† Throughput volume at breakthrough was estimated as no flow reading was taken at exactly the breakthrough point of 1.0×10^6 ohms.
‡ 4,190 gal tap water containing 300 ppm total solids added for makeup during the run.
§ 4,000 gal tap water containing 300 ppm total solids added for makeup during the run.
‖ 5,085 gal tap water containing 300 ppm total solids added for makeup during the run.
4,680 gal tap water containing 300 ppm total solids added for makeup during the run.

If it were assumed that the 20 ppm of total solids were $CaCO_3$, it would have been possible to pass about 1,500 gal of water through the column before having more than 1–2 cpm per milliliter beta-gamma activity in the effluent. At a flow rate of 2 gpm per cubic foot, 28 days of 8 hr each would have been required to exhaust the column.

Gamma Irradiation Facility Water

A very practical problem is the purification of water in gamma irradiation canals. Demineralized water is used in the gamma irradiation facility canal at the Argonne National Laboratory at Lemont, Ill., and at the Materials Testing Reactor at Arco, Idaho.

At Argonne, laboratory tap water was first used in the canal but as a result of precipitation of impurities in the water and the continually slow but notable increase in the radioactivity in the water from corrosion products, it was deemed advisable to demineralize the water. The canal contained 50,000 gal of water having a total dissolved solids content of 550 ppm, and 6,000 cpm per milliliter beta-gamma radioactivity. The water was passed through a mixed bed ion-exchange unit to remove this activity and, at the same time, to demineralize it. A spectrographic analysis indicated that the cations present, when calculated in terms of $CaCO_3$, totaled 350 ppm. Demineralizing this quantity of water in one pass would have required 40 cu ft of cation-exchange resin and 80 cu ft of anion-exchange resin, or an ion exchanger 4–5 ft in diameter and 10–15 ft high. A unit this size would be unwise economically, for once the water were demineralized, there would be very few either radioactive or nonradioactive ions to be exchanged. A 1,000-gph, 130,000-grain capacity exchanger was therefore purchased, containing a 2:1 ratio of anion to cation resin. The effluent from the exchanger was returned to the canal so that the canal water was being cleaned up at the rate of 1,000 gph and, at the same time, continuously diluted with completely demineralized water at the rate of 1,000 gph. The results of this process are shown in Table 7.

On the thirteenth run no tap water was passed through the mixed bed ion exchanger—only canal water was used. The maximum beta-gamma activity in the canal water during this run was 64 cpm per milliliter, and the minimum was 23 cpm per milliliter (50 per cent counting yield). The pH ranged from 7.5–6.6. Total solids were 0.85 ppm as $CaCO_3$, based on spectrographic analysis. Before the breakthrough point of 1.0×10^6 micromhos was reached 2,230,000 gal of canal water passed through the mixed bed. With a water containing 0.85 ppm total solids, it should have been possible to pass 2,600,000 gal through the mixed bed. No radioactivity was observed in effluent samples at the breakthrough point of 1,000,000 ohms resistivity, however.

Every effort is made to keep the amount of regenerants and the rinse water to an absolute minimum because all of these solutions contain radioactivity and must be further processed either by evaporation or storage. Because of incomplete rinsing, the first effluents after the resins have been regenerated may contain some radioactivity. In the thirteenth run the effluent from the first 60,000 gal passing through the mixed bed exchanger contained 15 cpm per milliliter, and after this, the counts dropped to 0–1 cpm per milliliter. The effluents on the sixteenth run, on the other hand, showed

almost no radioactivity until breakthrough when there was 1.5 cpm per milliliter.

It is to be noted that by recirculating even as small an amount as 1,000 gph through the mixed bed ion exchanger, the radioactivity in the canal water is not allowed to build up and remains consistently at 20 cpm per milliliter, unless the ion exchanger is bypassed. It is believed that if a demineralized water had been used at the outset, no radioactivity would be present in the canal water as long as it was continuously recirculated.

In the gamma facility at the Materials Testing Reactor, at Arco, Idaho, demineralized water is continuously added to the canal, and a portion is continuously discharged as waste. The demineralized water, however, is processed through separate cation and anion beds, and has a specific resistance of 300,000–500,000 ohms and a maximum dissolved solids content of 3 ppm (*9*). The gamma canal at the Materials Testing Reactor is 18 × 8 × 75 ft and contains about 80,000 gal of water. From 10 to 40 gpm of water is purged, and the activity varies from 250 to 2,000 cpm per milliliter.

Reactor Water

Water may be used in a reactor as a moderator, as a coolant, or as both. Three general classes of radioactive impurities may be present in this water: [1] corrosion products from the fuel cladding or from the materials of construction of the reactor vessel; [2] fission products from the fuel itself; and [3] induced radioactivity resulting from the absorption of neutrons by the water or by impurities.

The water used in a reactor may be either heavy (D_2O) or light water. If heavy, a closed system is used as in the Argonne CP-5 reactor, in which the water is continuously recycled, and a portion (0.3 per cent) is continuously bled and passed through filters and a mixed bed ion-exchange unit. In CP-5, two porcelain biological filters are used; one prior to passing the heavy water through the mixed bed exchanger, and one following it. The latter filter is used to catch any small resin particles which may have washed out of the column. The column is a 5-in. ID stainless-steel tubing, the resin bed is 40 in. high and contains 0.45 cu ft of mixed resins (2:1 ratio anion to cation *). The flow rate through the column is 4 gpm. The pH —or, strictly speaking, the pD—of the water is maintained at 6.5, the conductivity at 0.033 micromho, and the isotopic purity at 99.6–99.56 per cent. Pipes 6 in. in diameter carrying 100 gpm of heavy water directly from the operating reactor show an activity level of 1.5 roentgens per hour at the surface but this is all short-lived activity from the activation of oxygen and nitrogen. After shutdown of the reactor, all parts of the cooling system may be approached immediately for direct maintenance. Operating experiences of the Argonne reactors are presented in a paper by McCorkle and Zinn (*10*).

When using light water in reactors, if water or any impurities contained in the water are subjected to neutron bombardment, both become radioactive. This is known as induced radioactivity. Sivetz (*11*) has discussed induced radioactivity in water in some detail. Lyon and Reynolds (*12*) determined the radioactive species induced in demineralized cooling water subjected to

* Anion used was Amberlite IRA-400, and cation was Amberlite IR-120, both products of Rohm & Haas Company, Philadelphia, Pa.

a flux of about 4×10^{13} neutrons per square centimeter per second. This water was in contact with aluminum, stainless steel, cast iron, and carbon steel. The activities found were N^{16}, Al^{38}, Mg^{27}, Na^{24}, Cu^{64}, Mn^{56}, and Ag^{110}. With the exception of Ag^{110}, which has a half-life of 270 days, all of the half-lives were under 24 hr. These particular results would not necessarily be duplicated with water in another reactor.

The use of water in various types of reactors was summarized in a paper by Huntley and Untermeyer (*13*) who pointed out that, in the main, reactor water if used as a moderator must be of very high purity, although this is not true for all water used for cooling. The condenser cooling water for reactors, for example, does not usually become radioactive and, therefore, need only be processed to avoid fouling pumps, piping, and heat transfer surfaces.

There are conditions under which there is a remote possibility that the boiler feed water from a secondary loop might inadvertently enter the reactor. Consequently, it is customary to maintain the highest purity for secondary cooling loop water in reactor plants. To accomplish this, water is bled continuously from the boiler drum, cooled to 100°F or lower, filtered, deionized and reheated to the operating temperature of the system.

In the case of a boiling water reactor, steam is generated within the reactor and therefore becomes radioactive. This steam is used to operate the turbine. Untermeyer (*14*) discusses this problem in detail. A continuous repurification system consisting of filtration and mixed bed ion-exchange units is used to keep the water pure so that the radioactivity in the steam is due to short-lived products of neutron capture by the oxygen in the water. Untermeyer states that "calculations and available operating experience indicate that the radioactive deposits on the turbine will not prove to be prohibitive, as the radiation level during turbine overhaul will not exceed safe working tolerances."

Two papers have appeared recently dealing with water technology in pressurized water reactors. The first (*15*) was presented before the International Conference on the Peaceful Uses of Atomic Energy at Geneva in September 1955, and dealt mainly with corrosion problems. The second was presented at the Nuclear Engineering and Science Congress meeting in Cleveland (*16*) and covers the subject very adequately. The authors state that: "although troublesome, the radioactivity problems in a pressurized water reactor with high integrity fuel elements are probably minor compared with many other types of reactors." They list the radioactive nuclides (Table 8) in the primary system of an operating pressurized water reactor plant (Table 7), but are careful to point out that these activities would

TABLE 8

Typical Radionuclides of Coolant in an Operating Pressurized Water Reactor (16)

Nuclide	Half-Life	Source
N^{16}	7.3 sec	O^{16} in H_2O
N^{17}	4.1 sec	O^{17} in H_2O
K^{38}	7.7 min	?
A^{41}	1.8 hr	air in H_2O
F^{18}	1.9 hr	?
Mn^{56}	2.6 hr	steel
Na^{24}	15 hr	Na in H_2O
Co^{60}	5.3 years	steel
Fe^{59}	45 days	steel
Ta^{182}	111 days	steel

not necessarily be the same under other conditions, such as different structural materials, fuel cladding, water purity, and type of reactor. Water purity was maintained in the primary system by using bypass sintered stainless-steel filters in series with a mixed bed demineralizer. Resistivities of at least 10 megohm-cm were generally obtained, and removal of all radioactive constituents was essentially complete. The stainless-steel filters clogged easily and exhibited high pressure drops and, in later work, these filters were bypassed, as corrosion products in the influent ranged from 0.1 to 0.2 ppm. The demineralizers were sized to permit several weeks or months of operation before exhaustion and were not regenerated.

Mixed Bed for Waste Treatment

Based on the experimental work reported in the first section of this paper, it is assumed that a mixed bed ion exchanger should remove almost all of the radioactivity found in a waste up to the point of total solids breakthrough. Unless demineralized water has been used throughout, the cost of removing radioactivity by this means will be proportional to the amount of total solids present in the waste. With a water containing 300-ppm total solids, for example, only about 700 gal of water at pH 7.0 could be processed per cubic foot of mixed bed capacity before it was necessary to regenerate the resins.

The feasibility of removing radioactivity from wastes, therefore, will be predicated upon total dissolved solids in the wastes and volume of the wastes, in indirect proportion.

Contaminated Resins Disposal

Whenever the resins have served their usefulness they may be buried, incinerated, or disposed of in the ocean. Incineration, however, will require the clean-up of the gas stream by means of absorbers and filters.

Cost of Mixed Bed

The cost of mixed bed ion exchanger for any of the uses described in this article will be the same as for commercial demineralization plants, except in those cases where shielding of the ion-exchange beds is required.

In the case of the 130,000 grain capacity mixed bed unit installed at the Argonne National Laboratory gamma facility, a packaged unit was obtained costing $5,000 without installation charges, but including instrumentation and resins.

Summary

Experimental work using mixed bed ion-exchange resins for removing old mixed fission products from tap water showed that the highest decontamination factors were obtained when the water was adjusted to pH 2.5 with nitric acid. This adjustment increased the anion content of the water and it is therefore recommended that a 3:1 ratio of anion to cation resin be used.

Flow rate appears to be an important consideration in removing radioactivity and should not exceed 2 gpm per cubic foot of mixed resin.

The capacity of a mixed bed exchanger for the removal of radioactivity is based on the amount of total dissolved solids in the feed—the lower the dissolved solids content the larger the throughput.

Acknowledgments

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Advantages of Monthly Billing for Water Utilities

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A paper presented on Sep. 20, 1956, at the Ohio Section Meeting, Toledo, Ohio, by A. V. Agnew, Supt. Water & Sewage Depts., Lorain, Ohio.

THE idea of monthly billing in the water works industry has been an intriguing one for several years. Investigation reveals that in Ohio (*1*), in cities of more than 15,000 population, the billing periods used are distributed as follows: semiannual, 5; bimonthly, 1; quarterly, 34; and monthly, 5.

In the semiannual group are found two of Ohio's largest cities and three in the 30,000 population category; in the bimonthly class, a city of approximately 20,000; in the quarterly group, cities with population ranges from 15,000 to 600,000; and in the monthly group cities in a population range from 20,000 to 35,000. It is quite obvious that monthly billing is not a popular method.

Sixty per cent of the water works industry is deficient in either supply, treatment facilities, or distribution, and the reasons for this condition are usually stated to be insufficient funds, low income because of low rates, inflation, and politics and politicians.

The electrical power industry on the other hand, does not show this deficiency in its facilities. At Lorain, Ohio, the power plant capacity was doubled in 1948, and is, at present, practically doubled again. In this same period, although the water plant doubled in size, there is still much to do in the distribution system. Power utilities are apparently foresighted enough to keep ahead of demand; they are in business for a profit and must pay dividends to stockholders. Publicly owned water utilities, which, theoretically, at least, need only break even, are put to shame by the program of expansion of the privately owned utility.

The explanation, of course, is finances, and finances mean rates, and rates mean collections. There are few, if any, privately owned power companies which bill and collect quarterly. Yet, it is obviously cheaper to bill and collect four times a year than twelve times a year. It is curious then, that big power utilities, which are in business for profit, continue to bill on a monthly or bimonthly basis when a cheaper method is available.

At first glance it would appear that the reason for not adopting a quarterly payment plan would be the cash turnover available under a monthly system. But this reason would apply only to the first quarter of such an operation, because, by establishing zones of payment and by cycling the billing, the monthly income would be the same (after the first quarter) as is now available on a monthly basis. From a financing standpoint, a monthly system is no better than a quarterly. With easier financing eliminated as a reason, and with the increased cost of monthly over

quarterly billing, the reason must be better operation.

Public Relations

Good operation cannot exist without good public relations. By billing monthly, the bills are smaller, there is less delinquency and, consequently, less shutting off of service for nonpayment of bills. For the same reason, there are smaller overhead and service costs and—most of all—less public resistance to rate adjustments.

From the standpoint of public relations it is better to bill monthly, not only because of the smaller bills that result, but because the customer, knowing that he has a water bill due each month, will budget his payment the same as all other utility bills and will be able to compare the water bill directly to the gas or electric bill. Such a comparison would be very favorable to the water department in the vast majority of cases.

The steady per capita increase in water use resulting from the wide acceptance of automatic washers, garbage disposal units, automatic dishwashers, and air conditioning, has resulted in higher average water bills. This, together with summer sprinkling charges and sewage rental charges (adopted by more communities each year for sewage disposal financing) results, in many instances, in comparatively large summer bills, which, because of quarterly billing, fall due in November and December. Bringing the payment date closer to that of actual usage and allowing the customer to pay monthly rather than quarterly would do much to improve public relations—particularly in the period of excessive summer usage. By November and December, when the customer has completely forgotten how much sprinkling was done in July and August, and just before the holidays when other utility bills have begun to increase after the summer lull, he is confronted with an exceptionally high water bill. Invariably he complains bitterly about the size of the water bill, stating, "Why I hardly sprinkled at all during July and August," or something such as "We were away on vacation part of the time."

Budget Plan

Gas companies in Ohio have inaugurated what is termed a "budget plan." Under this plan the annual gas bill is estimated and a prorated part of such estimate is paid each month. Adjustments based on actual meter readings are then made. This, of course, levels off the peak bills and results in an almost equal monthly payment all year. According to the local gas company, there has been eager acceptance of the plan indicating public preference for a budget system of payment. Nearly all advertising nowadays is based on this idea; prices are ignored, and just the monthly payment needed is given.

Quarterly billing is completely out of tune with the times, and it is time, instead, to adopt not only monthly billing but a budgeted plan also. The Bureau of Inspection of Public Offices of the State of Ohio Auditor's Office has indicated that there were no objections to such a billing system, provided that good records were kept. In other words if the utility's "housekeeping" is good there would be no objection to the plan.

Conversion Program

A study has shown that in Lorain adoption of monthly billing on a bud-

get plan would require the following procedure. First, a change from the ledger plan to stub billing, followed by a classification of the accounts according to the amounts paid yearly by the various customers. An accounting addressograph machine would be purchased and each customer plate punched for the amount to be paid each month. The plates would then be fed into the machine which would tabulate the account numbers, the amount payable for water, sewer rental charges, the total of each, and a grand total. This record would constitute the accounts receivable ledger control. Such a machine will produce up to 3,000 bills per hour, automatically.

Present operation at Lorain is on a three-zone plan with billing cycled quarterly so that billing and collection are done each month. The payment period, without penalty, is from the first to the fifteenth of the month. On a monthly plan, billing would be cycled so that one zone would pay from the first to the tenth, another the tenth to the twentieth, and the third from the twentieth to the thirtieth. Up to the present, reading meters less than four times a year, as is now being done, has not been considered. Once the plan is put into operation, however, a frequency of two readings per year would be indicated, at which time the prorated bill would be adjusted. The adjusted bills would, of course, be run through the regular billing machine and the credits posted to the customer bill at that time.

The study indicated that no additional personnel would be needed to change from the present method of billing to the monthly budget plan. The only cost would be for the purchase of the equipment and the mailing charges. This cost could eventually be met by the swings of semiannual meter readings over quarterly readings. Even if the cost were greater, it is believed that intangible benefits would derive from the modernization of billing and collection by the adoption of the monthly billing plan.

Conclusion

Victor Weir said recently "Adequate income is the current prime problem for both publicly and privately owned water utilities. This is essential if rapidly expanding demands are to be met at today's inflated costs . . . and if adequate staffs are to be retained." He also stated, "It is difficult to educate John Q. Public that a financially healthy utility is to his best interest, but it must be done."

Since lack of sufficient income is the underlying cause of the industry's lagging behind demands made upon it and "John Q. Public is difficult to educate" then it must be made as painless as possible for Joe Smith to pay his water bill by adopting the monthly billing plan. Then, should rate adjustments ever be necessary, and they will be, a small monthly increase would be much more painless and much easier to sell than the same applied to an accumulation of three months of water usage.

It has always been surprising, when discussing "excessive" water bills with customers, that they seldom ever consider the fact that the bill is for 3 months' supply of water. The vast majority of people look upon a bill as an obligation of the moment with no thought given to the time of its accumulation. It is necessary, therefore, to increase the frequency of such moments. This may be accomplished by joining the public utility groups which

bill and collect monthly. There is no better way for the water works industry to get the income needed to meet all the demands made on it. In the future, perhaps, the industry will find itself in the enviable position of the other large public utilities.

Reference

1. Bulletin on Water Rates in Ohio. Ohio Department of Health (1954).

Discussion

Harry E. Jordan

Secy., American Water Works Assn., New York, N.Y.

The author has presented a stimulating study of the values derived from frequent reading of customer's water meters. The connection which he observes between advanced planning, adequacy of facilities, and frequency of meter reading, is not, however, as rigid as might be thought. There can be no question that advance planning of water supply facilities is greatly needed in many of the properties over the country. It is also evident that there is more than a casual relationship between the lack of advance planning on the one hand and the lack of facilities already installed to meet the consumer's demands on the other hand.

The point in the author's paper which must be critically examined is the emphasis he places on the superior value of monthly billing—both as a matter of business and as good public relations. Some of the very best managed water utilities in the United States continue to read meters and bill customers quarterly; for example: Akron, Ohio; Birmingham, Ala.; Denver, Colo.; Detroit, Mich.; Miami, Fla.; Milwaukee, Wis.; New Haven, Conn.; St. Paul, Minn.; and St. Louis County (Mo.) Water Co. These properties are all well managed and keep abreast of the consumer demands, yet they continue, for reasons sufficient to their management, to read and bill quarterly. Beginning in the war years with the example of the very efficient Los Angeles Water Dept., meter reading and billing on a bimonthly basis has extended to such cities as Atlanta, Ga.; Chicago, Ill.; Gary and Indianapolis, Ind.; Kansas City, Mo.; and Louisville, Ky.

A perusal of the AWWA survey of operating data for water utilities in 1955, published in the May 1957 JOURNAL (*1*), discloses a very substantial number of water utilities which continue to read meters monthly. Reference to Column 15 of Table 2 of the survey, which shows the percentage of unaccounted-for water, and to Column 10 of Table 3, which gives the frequency of meter reading, discloses the fact that there is no straight-line relationship between the two. One would hope that such a relationship existed, but the record does not so indicate.

Reference

1. STAFF REPORT. A Survey of Operating Data for Water Works in 1955. *Jour. AWWA*, **49**:553 (May 1957).

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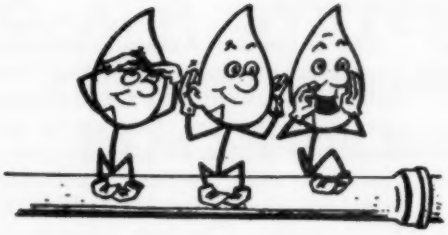

Percolation and Runoff

The Governors' Conference one of these years is going to resemble an AWWA get-together if the current trend toward gubernatorial membership continues. Now it is Governor C. William O'Neill of Ohio who has taken this means of indicating the importance he attaches to his state's water supply problems. Signing up Ohio's first citizen was Section Chairman M. W. Tatlock, consulting engineer from Dayton, who has also indicated that the governor is giving consideration to appointing a representative of AWWA on the state's new nine-man study committee on water resources and conservation. Much more than a publicity stunt, this enrollment of governors is an important means of gaining recognition not only for AWWA, but for public water supply's proper place in the state water resources picture.

The trend, of course, is a little tentative yet, with only 4.167 per cent of the nation's governors enrolled (which is to remind you that Governor Handley of Indiana became a member in April), but with Section competition so keen these days, we can hardly suppose that it will be long before at least Michigan and Pennsylvania catch up to their archrivals in this aspect of their membership races. As a matter of fact, the Pennsylvania Section could even take the lead if, in addition to their Leader, they obtained an application from a certain Gettysburg address. That, of course, could be complicated by the Chesapeake Section, or perhaps by Kansas, or even the Rocky Mountain.

At any rate, the goal is 48 by '58!

A crystal ball look at percolation and runoff 6 months hence is now being offered to the water works field by one Lyle E. Brosché of Dearborn, Mich. To those who have had extreme difficulty in making any sense at all of Percolation and Runoff right here and now, we hasten to explain that it is strictly uncapitalized p&r—the real coin of the water supply realm—at which The Brosché Method offers a future look, the Methodical Lyle E. being a meteorologist who, after many years of specialization in temperature forecasting for the heating industries, has expanded his long-range forecasting technique to include precipitation as well.

Essence of the Brosché bid for water works business is the offer of 6-month forecasts of temperature and precipitation for any given area, the

(*Continued on page 46 P&R*)

(Continued from page 45 P&R)

forecasts being made available on the first day of the 6-month period (October–March or April–September) involved. By such clues as comparisons with "normal" and with the previous year's experience, as well as by 3-month subtotals, these forecasts purport to provide the basis "for advance planning purposes to insure adequacy of supply, for determining certain maintenance requirements, and for calculating long-range sales and earnings."

There is no question, of course, that it would be of some interest and value to water works men to know on Apr. 1 whether the coming summer is to be "hot/dry," "cool/dry," "hot/wet," or "cool/wet," the four broad classifications, which, with very's, provide a guide to the simmer season. With dryness on tap, conservation campaigns can, at least, be undertaken earlier, and with wetness in prospect, the water works man can perhaps plan a peaceful vacation. In view of the number of years required to promote, design, and build water works facilities that will "insure adequacy of supply," however, it is difficult to see how a 6-month forecast can do much more than suggest a propitious time to get a promotional campaign under way. All of which may suggest that, for the present at least, the Brosché Method may be of more use to the water works man in his public relations planning than in any other aspect of his operations.

What the water works field actually needs is a guaranteed 50-year forecast of p&r. Meanwhile, those interested in the 1 per cent now being offered unguaranteed will find the Brosché ball at 22444 Lawrence Ave., Dearborn, Mich.

The Pitometer Assocs. announces a number of changes affecting the firm's top posts. E. D. Case, president since 1946, becomes chairman of the board, with E. Shaw Cole, vice-president and chief engineer, becoming president. Succeeding Mr. Cole is H. E. Beckwith. The new position of principal engineer will be filled jointly by W. D. Hudson, presently assistant chief engineer in charge of the Atlanta office, and J. M. Shanley, now in charge of the Houston office.

John Ware, chairman of the board of American Water Works Co. and Northeastern Water Co., has received a Horatio Alger Award, one of eleven presented this year by the American Schools & Colleges Assn. to prominent business, industrial, and professional leaders in recognition of success in their fields through hard work, honesty, and determination despite humble beginnings. The first utility man ever to receive the award, Mr. Ware achieved success in both the electric power and the water works field, retiring from the former in his thirties as a millionaire to take over the old National Waterworks Co., which was in financial difficulties. Now 69, he is board chairman of the largest privately owned water system in the United States, serving more than 4,000,000 people in twenty states.

L. L. Hedgepeth has been appointed adjunct professor by Rutgers University, New Brunswick, N.J. He will assist in the teaching and research activities of the Dept. of Sanitation on a part-time basis, continuing in his present position as senior consultant in water sanitation to American Cyanamid Co.

(Continued on page 48 P&R)

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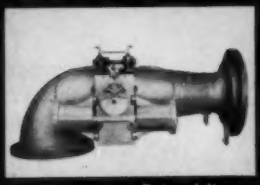

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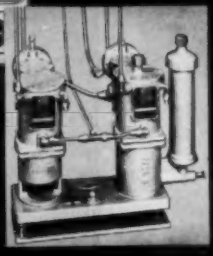

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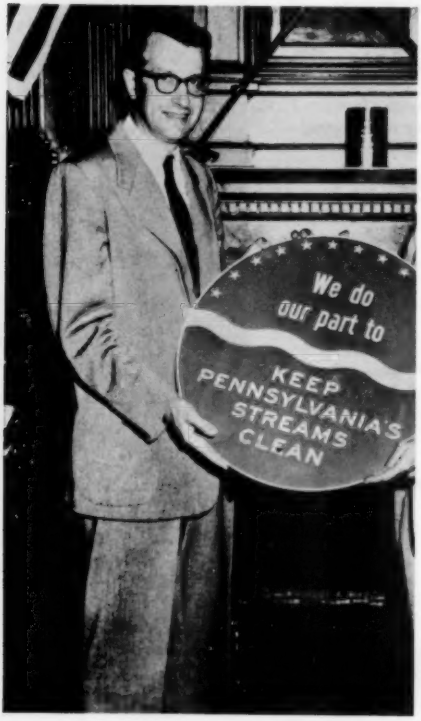
(Continued from page 46 P&R)

The Clean Streams Program, sponsored by the Water Resources Council, Inc., of which AWWA, FSIWA, WSWMA, and sixteen other national organizations in industry, conservation, and civic affairs are members, has enlisted an important supporter in Governor George M. Leader of Pennsylvania, who recently initiated a voluntary civic drive that expects to enlist every waterside community and industry in the state in the pollution abatement effort. Manufacturers and municipalities who qualify as active supporters of the program will be entitled to display roadside markers of the type the Governor displays above, but if Pennsylvania's pollution is anything like that elsewhere, the most obvious sign will be the change in the water itself—its appearance, its odor, and, finally, its taste. Clean streams mean not only better water, but, because pollution in extremes makes ex-streams as far as water supply is concerned, more water as well.



Graver Tank & Mfg. Co., Inc., is celebrating its 100th anniversary this year. The original labor force of two Graver brothers has grown to more than 4,000, employed in plants and divisions across the country. As part of its celebration, the firm is offering prizes of $100 each for information on the location of the oldest Graver tank still in use and for the oldest picture of one of its tanks. In addition, a $500 first prize and two $250 second and third prizes are offered for the best idea for decorating a Graver tank (either in existence or planned). Entries must be mailed before Nov. 1, 1957, to: Centennial Committee, Graver Tank & Mfg. Co., Inc., East Chicago, Ind.

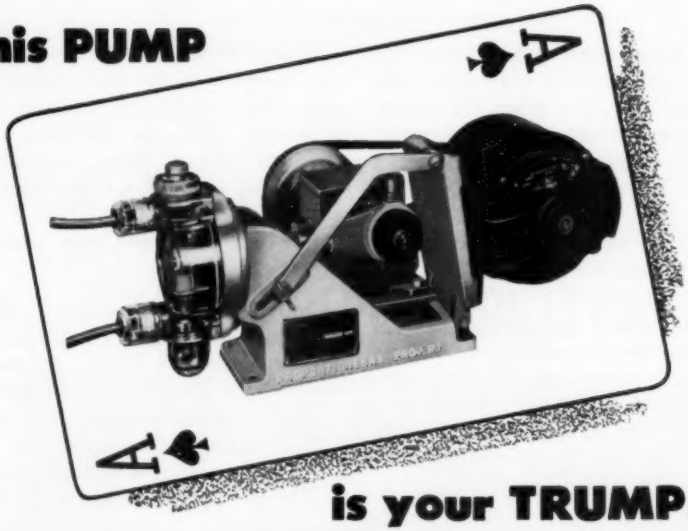
Major C. Hagar, public water supply and sewage works specialist, of Sterling, Kan., has accepted the position of water superintendent at Sioux Falls, S.D.

E. W. Herrmann has retired as eastern and export sales manager for American Cast Iron Pipe Co., after 42 years with the company. His successor is J. D. Fillmer.

Alden E. Stilson & Assocs., consulting engineers, Columbus, Ohio, have opened a second office at 2060 E. 9th St., Cleveland.

(Continued on page 50 P&R)

This PUMP



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(Continued from page 48 P&R)

50–50 is the story of a centennial at Erie, Pa.—a two-man centennial celebrated last Apr. 29, when the superintendent and assistant superintendent of Erie's water bureau completed a combined 100 years of service. "Jack Johnson and George Papesch Day" was what the mayor proclaimed it and a real Day it was for these two AWWA stalwarts, topped off by a testimonial dinner at which more than 300 of Erie's first citizens paid tribute to their water suppliers not only for the length of their service, but for the strength of their service as well. It isn't often that any one man completes 50 years of employment in a single organization, so when two in the same department reach that goal in the same year, it is certainly Day time.

Well did the 1,200 AWWA members and guests at the annual banquet in Atlantic City in May give Jack and George an ovation and well may the rest of us join in, not only for that first and hardest hundred years, but for that next and easy hundred on which they have already embarked—still on a 50–50 basis.

E. Clinton Smith has been named general manager of the Birmingham, Ala., water works, a post left vacant by the recent death of Herman L. Shiflett (see this issue, p. 96 P&R). Mr. Smith served as assistant general manager from 1949 until February 1957, when he accepted the position of general manager with the St. Joseph (Mo.) Water Co.

S. G. Paddock has been named executive vice-president of Burgess-Manning Co. Mr. Paddock was formerly vice-president in charge of the firm's Industrial Silencer Div.

Helen Rotthaus, clerical supervisor and secretary to the commissioner, Arizona Dept. of Health, has left to take a position with the Maricopa County Medical Society. Mrs. Rotthaus, who first came to work for the department in 1937, received the AWWA Fuller Award in 1950, the only woman so honored.

Iodization of water, over which the first battle of "mass medication" was fought almost 35 years ago, now appears ready to make a comeback, still in the business of preventing disease, but by acceptable disinfection rather than controversial supplementation. It was at the April meeting of the American Chemical Society in Miami that a symposium on the growing importance of inexpensive iodine preparations in the field of disinfection and sanitation procedures brought out the fact that iodine will destroy certain pathogenic organisms—the virus of infectious hepatitis, for instance—that chlorine will not. It was on this basis that the Army substituted iodine tablets for Halazone for use in disinfecting canteen water; and it is this greater effectiveness as well as greater efficiency that has been given as a reason for the use of iodide in disinfecting public water supply. Without worrying about the practical and pocketbook problems involved, we sort of wonder if goiter prevention would still be "mass medication" as an incidental benefit of iodide disinfection—that is, if fluoridation proponents might not find it worth while to sponsor research into some more generally acceptable water treatment uses of fluorides to which the caries prevention benefits could then become incidental. Not incidentally, however, we wonder what price water forever amber.

(Continued on page 52 P&R)

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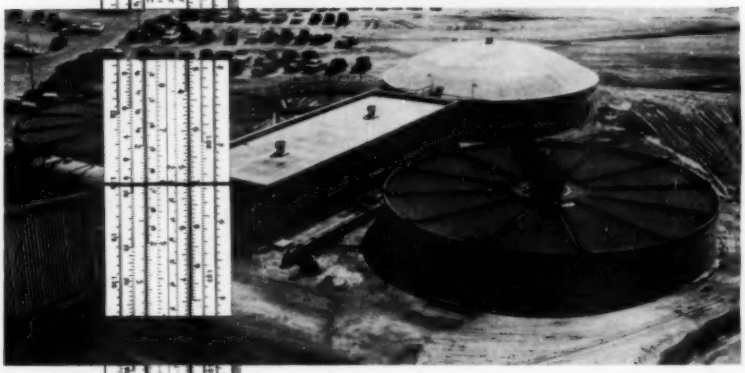

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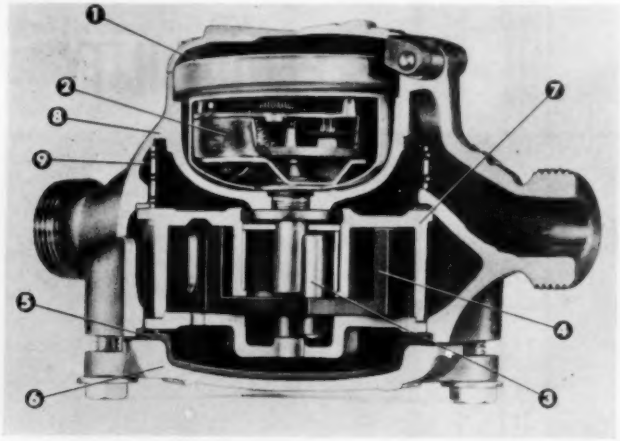
(Continued from page 50 P&R)

A water meter utilizing magnetic force to transmit motion from the measuring chamber to a hermetically sealed register has been announced by Rockwell Mfg. Co., Pittsburgh. The "Rockwell Sealed Register Meter" introduced at the Atlantic City Conference of AWWA earlier this year, contains fifteen stock parts, with only two moving parts operating in contact with water. Replacing the separate intermediate gear train and stuffing box of conventional meters are two permanent magnets. One magnet (Item 3 in photo) is contained in the oscillating piston (Item 4) in the measuring chamber; the other travels in a well in the sealed register (Item 2). The new meter, said to provide increased accuracy and efficiency while reducing maintenance costs, is presently made in $\frac{5}{8}$-in. and $\frac{5}{8} \times \frac{3}{4}$-in. sizes.



The consulting firms of H. E. Bovay Jr. and Reg F. Taylor have merged. The Bovay firm name will be retained and headquarters will remain at Houston, Tex.

(Continued on page 54 P&R)

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(Continued from page 52 P&R)

Baseball may not be business, but business, these days, seems to be making a pretty good pass at being baseball. Thus, in industry as on the diamond, this is the era of the lively ball, when sales, production, and profits, like homers, triples, and doubles, are continually topping all previous records. Just how much bigger and better things really are is a little difficult to tell through the obfuscation of the lighter dollar and the livelier ball. Sales to the water works field, for instance, have to be almost three times as high as they were in 1940 to be as high as they were in 1940—three times as high in dollars, that is, to be as high in units sold. And with production and profits measured in the same dollar terms, it's little wonder that Willie Miranda may at times look like Babe Ruth. Actually in business, if not in baseball, there undoubtedly has been real improvement—of which the nation's standard of living is, of course, the best proof. Not bad either—especially for the young engineer—is business's adoption of baseball's bonus system for recruiting its new personnel.

What we're concerned about, of course, is the fact that the water works field has somehow managed to work itself into the unhappy position of using the dead ball at bat and the lively one in the field—collecting 1940 or earlier rates to pay for 1957 plant and labor. And with population growth at an unprecedented level and suburban growth even unprecedenteder, new and expensive plant installed by expensive labor is an inescapable fact of life. All of which means that if the water works doesn't soon learn how to play the same brand of ball that industry is playing, even a full team of Babe Ruths won't keep it in the league. Tennis, anyone?

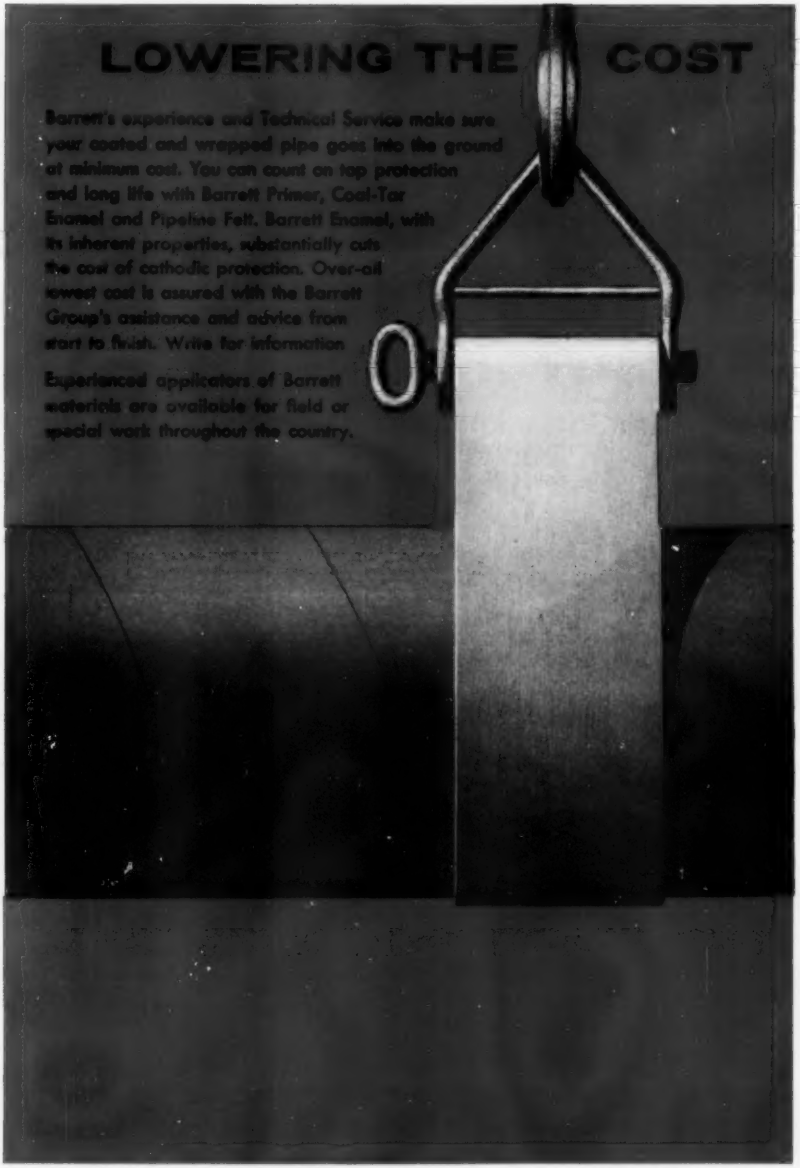
Howard Scott Morse, chairman of the board, Indianapolis (Ind.) Water Co., has been made an honorary member of ASCE. He received similar recognition from AWWA in 1952, as well as the Fuller Award in 1953.

Mr. Neptune, in the person of John Ballantine, president of the meter company of that sea-godly name, was really in his element last Jun. 30 when he effected the rescue of three people who had crashed their seaplane into New York City's East River. Not with trident, but *Tritonia*—his 85-ft yacht—this latter-day Neptune beat police launches, Coast Guard boats, and a helicopter to the scene and carried off both victims and winged victimizer, delivering them to the nearest landing for repairs. Thanks to John on the spot no one was seriously injured—thanks, that is, to Neptune!

Perry A. White, general controller of Baldwin-Lima-Hamilton Corp., Philadelphia, has been named vice-president and general manager of the firm's Eddystone Div., Eddystone, Pa. At the same time Robert G. Tabors, vice-president and assistant general manager of the Hamilton Div., Hamilton, Ohio, has been named vice-president and general manager of the Electronics & Instrumentation Div., Waltham, Mass.

I. E. Boberg has been elected vice-president of Chicago Bridge & Iron Co., Chicago. He has been chief engineer since 1945.

(Continued on page 56 P&R)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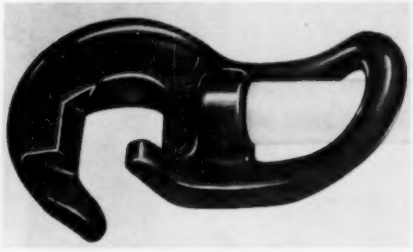
(Continued from page 54 P&R)

E. Bruce Meier, associate professor of civil engineering, Univ. of Nebraska, Lincoln, has joined the consulting firm of Kirkham, Michael & Assocs., Omaha, and will direct its activities in the sanitary engineering field.

A pipe puller designed by Reed Manufacturing Co., Erie, Pa., for vertical lifts on ¾–2-in. pipe in well drilling is said to be finding special application by water departments when renewing old and corroded curb-to-house water lines without ditching. An access pit is dug at the curb, the old line broken, and a coil of copper water tube



attached. The Reed puller is then used to grip the basement end of the line, and a hydraulic jack, bearing on the foundation, pulls the old pipe into the basement, bringing the copper tube along. Made of ductile iron with hardened jaws, the puller is said to withstand stresses in excess of 10,000 psi. Details are available in the manufacturer's Bulletin PL-11.

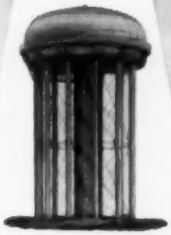
James N. Landis, vice-president, Bechtel Corp., San Francisco, has been nominated for president of ASME, to take office in December. He will succeed William F. Ryan, vice-president, Stone & Webster Eng. Corp., New York.

Economic ambassadors is what New Jersey's Governor Meyner appointed the executives of his state's financial, business, industrial, and utility organizations last month in opening an intensive drive to attract new business and industry to the state. Ministers with portfolio they will be, too—each of them having received a portfolio stressing the advantages of doing business in Jersey. The only trouble is, the portfoliation makes pretty dry reading—and will continue to until New Jerseyites do something more positive than arguing about new water supplies. In reporting the come-hither campaign, the New York *Times* stressed the fact that "the only utilities failing to keep pace with the industrial development appear to be those that furnish potable and industrial water." And the strength of the opposition to the various solutions suggested (see p. 969, this issue) would seem to indicate that the failing is likely to persist—the newest dam plan being no less damned than its predecessors. All of which is to suggest that the new ambassadors better not economize on their diplomacy concerning New Jersey's water.

P. N. Engel, president of Infilco, Inc., for 55 years, has been elected chairman of the board. Succeeding Mr. Engel as president is J. S. Gustafson, executive vice-president since 1953.

Formation of the firm of Geraghty, Miller & Hickok, consulting ground water geologists, with offices at 110 E. 42nd St., New York City, has been announced by the principals, James J. Geraghty, David W. Miller, and E. A. Hickok, all of whom have been in private consulting practice.

(Continued on page 58 P&R)



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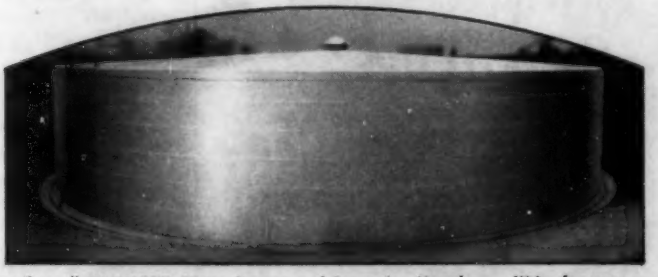

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(Continued from page 56 P&R)

Texaspiration is the word for a plan that Al Boerner, Dallas engineer, had worked out when he went to Washington earlier this year to propose construction of a 1,500-mile pipeline to carry water from the Great Lakes to Texas. Not only because the seven-billion-dollar price tag on the project involved a little more ready cash than even Texas has, but because matters of security and interstate interest were involved, Al decided to deal his Uncle Sam in. And the project is big enough for both of them—the underground pipeline, to consist of four 24-ft diameter tubes, is scheduled to provide for: a toll superhighway on top, with removable center strips to permit its quick conversion into a virtually endless airstrip; the shipment of bulk cargo through the line sealed in watertight capsules; and the use of the line by the Navy to transfer submarines from the Great Lakes to the Gulf "in complete security." Faced, but not fazed, with the possibility of objections by the Great Lakes states, Al points out that, if Texas' thirst threatens to lower levels seriously, it would be a "simple" matter to divert the water now flowing north into Hudson's Bay to keep the lakes full. Of course, if he would make some provision for en route taps, he might also develop the necessary exTexas support.

Knowing how snarled politicians can get things, particularly when at least ten states and a province are involved, we have an idea that the Boerner Plan will die aborning. No matter, though,

(Continued on page 60 P&R)

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(Continued from page 58 P&R)

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Radioactivity testing equipment has been installed in radiological laboratories at five New York State colleges as part of a State Dept. of Health program for checking the safety of water supplies in the event of atomic attack. Under the agreement between the department and the colleges, the state will maintain the equipment, and the institutions will furnish trained personnel ready to operate the laboratories at any time. The laboratories may also be used for training and research projects, including analyses of local bodies of water. Participating in the program are Cornell University, Ithaca; the state agricultural and technical institutes at Morrisville and Alfred; Vassar College, Poughkeepsie; and Orange County Community College, Middletown.

Greeley & Hansen, consulting engineers, Chicago, announce that the partnership of the firm now consists of: S. A. Greeley, P. E. Langdon, T. N. Niles, K. V. Hill, S. M. Clarke, G. M. Hite, Donald Newton, C. W. Reh, and M. D. R. Riddell.

Fischer & Porter Co., Hatboro, Pa., and Paterson Eng. Co., London, England, announce the formation of a new British company to be known as Chlorination Equipment, Ltd.

(Continued on page 62 P&R)

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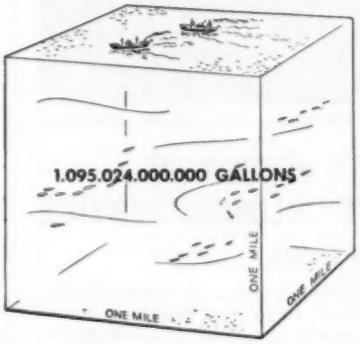

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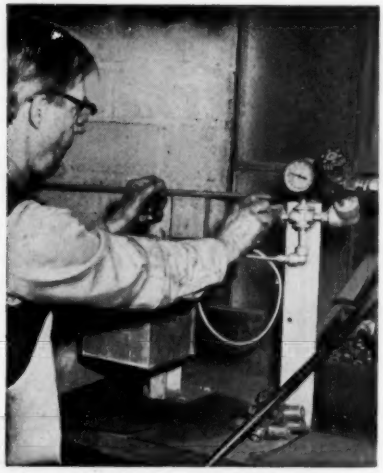

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(*Continued from page 60 P&R*)

Mars bars human habitation unless it has the two basic necessities: water, of course, and oxygen. Thus, with space travelers presumably breathing down their necks, astronomers are now making a spectrographic search for these essentials on our neighbor planet. One of the problems in the prospecting, as described by Dr. Robert S. Richardson of the Mount Wilson Palomar Observatories in a speech before the International Mars Committee recently, is that of separating earth oxygen from Mars oxygen in spectrographic recordings made at the earth's surface. The answer, on which astronomers are now working, is to send spectrographic equipment aloft in balloons and rockets that go above the earth's atmosphere. If the search is successful, a full list of employment opportunities will be published in the JOURNAL's classified section. Meanwhile, it may be well to suggest that we keep our space suits in mothballs and bend our efforts to convincing Martian astronomers that we really do have water here.

'Plastic Steel' is included in an emergency repair kit offered by Devcon Corp., 1220 Endicott St., Danvers, Mass., for tanks, pipe, pumps, and valves. The substance, a combination of 80 per cent steel and 20 per cent plastic, can be formed into any shape and is said not to run or sag when applied to a vertical surface. It can be hardened by heat in 60 sec, or without heat in 2 hr by adding a hardening agent supplied with the kit.

Dan R. Gannon has been appointed field sales manager for Mueller Co., Decatur, Ill. He was formerly western sales manager at Arcadia, Calif.

(*Continued on page 92 P&R*)

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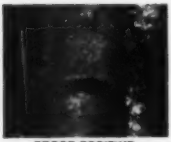

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Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

FLUORIDATION

Effect of Fluoridated Public Water Supplies on Dental Caries Prevalence. F. A. Arnold Jr. et al. Public Health Repts., **71**:652 ('56). This paper summarizes findings of 10-yr study in Grand Rapids and Muskegon, Mich., which was undertaken to det. value of adding fluorides to public water supplies in effort to reduce incidence of dental caries. General procedure and results are presented in detail. After discussion of results, authors note following benefits from addn. of fluoride to concn. of approx. 1 ppm: 1. Striking reduction in prevalence of dental caries in deciduous teeth. 2. Marked reduction in prevalence of dental caries in permanent teeth. 3. Some benefit among persons whose teeth have already formed or erupted when fluoridation is begun. It is pointed out that there is "no undesirable cosmetic effect from dental fluorosis."—*PHEA*

Present Status of Controlled Fluoridation in the United States. Public Health Repts., **71**:963 ('56). Summarized is present status of controlled water fluoridation in US. Summary data include number of communities, water supply systems, and pop. served by fluoridated water; date procedure was instituted; ownership of water plant, and authorization for fluoridation. These data are presented primarily as reference material.—*PHEA*

Selection of Equipment for Water Fluoridation. J. D. Reid. Munic. Utilities, **94**:53 ('56). Choice of fluoride compd. types of feeding equip., point of application to treated water, and ancillary equip. for control and recording of fluoride concn. in fluoridation of public water supplies are discussed. Diagrams of some fluoridation equip. are given. —*WPA*

Dental Observations on Australian Aborigines: Water Supplies and Endemic Dental Fluorosis. M. J. Barrett. Australian Dental J., **1**:87 ('56). Water intake habits of group of full-blooded Australian aborigines living in settlement conditions is outlined. Samples of water collected from rockholes, waterholes, soaks, and springs contain 0–0.4 ppm F. Bore water contains approx. 1.5 ppm F. 30 natives 6–20 yr. of age show signs of very mild or mild mottled enamel.—*CA*

Control of Fluoridation and Regulation of Dosage. G. M. Galimbert. Munic. Utilities, **94**:55 (56). Importance of accurate calibration of feeding equip. to regulate addn. of fluoride compd. to rate of flow of water in fluoridation of water supplies is emphasized. Chem. detn. of fluoride concn., methods for which are described, should be secondary to regulation of dosage. Consistent concn. of fluoride in water supplies of some Ontario communities practicing fluoridation is discussed. Precautions necessary for safe handling of solid fluoride chemicals are given.—*WPA*

Dental Caries of the First Molars and the Age of Children When First Consuming Naturally Fluoridated Water. R. M. Grainger & C. I. Coburn. Can. J. Public Health, **46**:347 ('55). Study of incidence of dental caries in deciduous and permanent first molars of children consuming naturally fluoridated water, in which concn. of fluorine ranged from 0.8 to 1.2 ppm, when related to age at which children started consuming fluoridated water, showed that there was less decay of permanent first molars of children born in area or moving in before age of 5 yrs as compared with children arriving after 6 yrs of age; difference was less significant in case of deciduous molars. It is inferred that protection from dental caries

(*Continued on page 74 P&R*)

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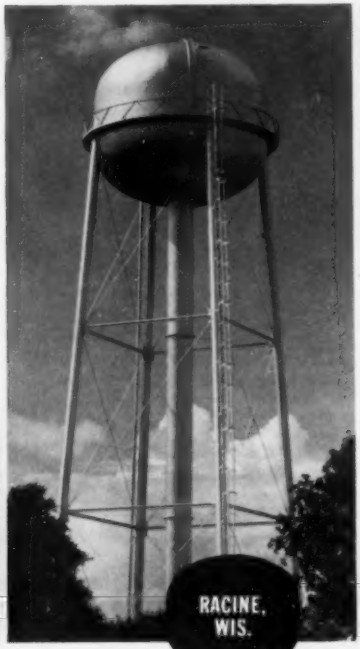

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(Continued from page 72 P&R)

afforded by presence of optimum quants. of fluorine in water is effective if consumption of fluoridated water starts before second stage of calcification of enamel, or about 1 year before tooth eruption, and that teeth of children which erupt after few mo. of ingestion of fluoridated water may show reduced susceptibility to dental caries.—*WPA*

Fluoride Content of New Brunswick Water Supplies. H. V. PRITCHARD. & B. W. COWAN. Can. J. Public Health, **46**:158 ('55). Before fluorides can be added to water supplies, it is essential to know concn. of fluoride occurring naturally, and survey was carried out to det. concn. of fluoride in different water supplies in New Brunswick. Results obtained range from 0.46 ppm to 2.66 ppm fluoride.—*WPA*

Status of Water Fluoridation in Canadian Municipalities. A. E. BERRY. Munic. Utilities, **94**:20 ('56). In report on status of water fluoridation in Canada, it is stated that 17 communities are supplied with water artificially fluoridated with either sodium fluoride or sodium silicofluoride, and that water supplies of about 40 communities in Ontario contain fluorides naturally present in a concn. of 0.7 ppm or more. Statements of policy, in support of fluoridation of water supplies as health measure, proclaimed by medical and health associations in Canada are quoted, and organizations in USA passing similar resolutions are listed. Extracts are given from reports on beneficial effects on teeth of children attributed to use of water fluoridated to optimum concn. of 1.2 ppm at Brantford, Ont. 2 court actions in Canada on legal right of municipal authorities to fluoridate water supplies are cited. In case of *Forest Hill* v. *Metropolitan Toronto,* judge's decision is given verbatim on question of whether legislation creating Metropolitan Toronto contained authority to fluoridate water supplies; it was concluded that Metropolitan authorities were within legal rights in taking this action.—*WPA*

Fluoridation of Water Supply. The Norway, Maine, Study. A. H. GARCELON. New Engl. J. Med., **254**:1072 ('56). Fluoridation of water supply of Norway, Me., is effected by addn. of sodium silicofluoride, giving residual concn. of 1 ppm fluoride. After 30 mo., investigation was carried out into condition of teeth of children between ages of 6 and 9, and on those of older age groups. Avg. number of decayed, missing and filled teeth fell by 80% for those of 6 yrs of age, by 28% for those of 9, and only slightly for those older.—*WPA*

Fluoridation Reduces Dental Caries in Evanston School Children. E. J. KNUDSEN. Public Works, **86**:91 ('55). As result of addn. of sodium fluoride to water supply of Evanston, Ill., incidence of dental caries in school children has been reduced by 46.42% over last 10 yrs. Sodium fluoride is administered with great care, gravimetric feeder being employed to feed sodium fluoride into system. Precautions taken to prevent possibility of adding toxic doses are given. Complete treatment consists of preliminary chlorination, coagulation with aluminium sulfate, addn. of activated carbon to control odor and taste, addn. of clay to control turbidity, filtration, postchlorination, and fluoridation.—*WPA*

Urinary Fluoride Levels Associated With Use of Fluoridated Waters. I. ZIPKIN ET AL. Public Health Repts. **71**:767 ('56). Authors describe study which was undertaken to find relation between amt. of fluoride in drinking water and amt. excreted in urine, time required for this relation to become stabilized, and effect of age on time required for equil. to be set up. 2 areas studied were Montgomery County, Md., and Grand Rapids, Mich. It was found that for drinking water containing 1 ppm fluoride, water and urinary fluoride concn. took 1 wk. to become approx. equal for adults, and in children between ages of 5 and 14, period was approx. 3–5 yrs. From this difference in time it is inferred that maturity of human skeletal tissue influences its capac. to retain fluoride. Methods of urine sampling are given. Findings give evidence that no cumulative toxic fluorosis can be associated with drinking water contg. 1 ppm fluoride. Results of studies are given in tables.—*WPA*

Incipient Fluorine Intoxication From Drinking Water. G. L. WALDBOTT. Acta Med. Scand. (Sw.), **156**:157 ('56). Evidence based on data from 52 cases con-

(Continued on page 76 P&R)

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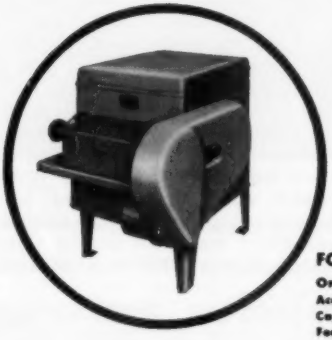

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(Continued from page 74 P&R)

firms previous observations that fluoride-contg. drinking water in concns. around 1 ppm accounts for characteristic syndrome. Variety of diseases may be due to or aggravated by traces of F in air, food, and water. —*CA*

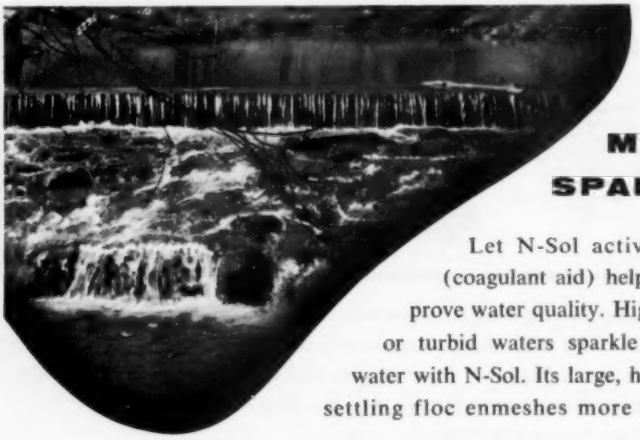
Preventing Dental Fluorosis by Using Low-Fluoride Bottled Water. N. F. Gerrie & F. Kehr. Public Health Repts., **72**:183 ('57).—*CA*

Posteruptive Effects of Fluoridation on First Permanent Molars of Children in Grand Rapids, Michigan. R. L. Hayes & N. W. Littleton. Am. J. Public Health, **47**:192 ('57).—*CA*

FOREIGN WATER SUPPLIES —GENERAL

The Water Supply of Sydney, New South Wales. J. Brit. Wter. Wks. Assn., **38**:54 ('56). Historical review is given of development of water supply systems for Sydney, N.S.W., from its establishment in 1788 to present day; these developments have kept in line with pop. growth from 1,000 to 2,000,000 persons in Sydney Metropolitan Water, Sewerage, and Drainage Board area. With completion of Upper Nepean Catchment Scheme in 1888, earlier water supply systems were abandoned. Upper Nepean Scheme involved tapping head waters of Nepean R. and its tributaries, Cataract, Cordreaux and Avon rivers, to dischg. into Prospect Creek impounding reservoir of 11 bil gal capac., from which it was taken by canal to Pipe Head basin, and thence by pipeline to Potts Hill service reservoir for distr. in Sydney. Subsequently dams were built on 3 tributary rivers to increase storage capac.; Prospect Creek became service reservoir and Potts Hill balancing reservoir before final conveyance to city through duplicated mains, interconnected to permit cleaning and maintenance. Water distr. systems within metropolis and for neighboring municipalities are described. Supplementary

(Continued on page 78 P&R)



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(Continued from page 76 P&R)

water supply schemes are outlined. In 1941, constr. of dam on Woronora R., south of Sydney, giving 15.79-bil gal storage capac., was completed. To meet future demands storage capac., at present 124.96 bil gal, is being increased by constr. of dam on Warragamba R., largest of Nepean tributaries. Prior to completion of dam, constructional details of which are given, river water is pumped through 106-in. diam. pipeline, at present connected to diversion tunnel circumventing dam site, to Prospect Creek Res. Water from Prospect Creek Res. is screened and chlorinated only under emergency storm conditions. Present distr. system, with 109 service reservoirs and 41 pumping stations delivers 59.81 bil gal of water per yr.—*WPA*

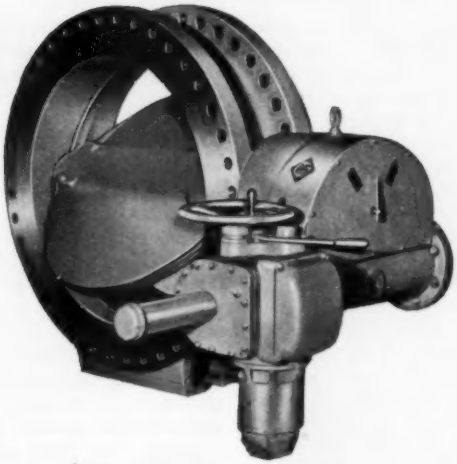
Water Supply—Sources, Storages and Treatment. J. B. K. Ley. Commonwealth Engr. (London), **43**:384 ('56). Author discusses problems encountered in control of poln. and provision of water supplies in densely populated European countries, and points out that rapid development in Australia, especially in interior, may soon result in inadequate water resources and increasing risk of poln. He suggests that covered service reservoirs may eventually be necessary.—*WPA*

The Water Supply of Dusseldorf. P. Schenk. Gas- u. Wasserfach (Ger.), **97**:773 ('56). Development of Dusseldorf water supply since constr. of first pumping plant in 1870 is described and more detailed account is given of recent addn. to water works. These include 2 pumping plants on Grind, an area of land almost surrounded by Rhine, new pumping plant at water works at Staad. These new plants use horizontal filter wells instead of vertical filter wells of older works. Constr. of these wells is described. Works on Grind serve Wuppertal as well as Dusseldorf. Total Dusseldorf supply, which is also used by number of neighboring communities, comprises about 80% bank filtered Rhine water. With new pumping plants planned for Grind area supply is satisfactory in quant. but increasing poln. of Rhine raises problems of qual. Tastes and odors appear in bank filtered water not only at low water but at higher flows. Expts. with animals have shown that at present there is no danger to health but this might not be case if poln. increases. Investigations are in progress under Arbeitsgemeinschaft Niederrhein-Wasserwerke into possible methods of treatment. At present main expts. are on treatment with ozone, active carbon, and chlorine dioxide. Results in exptl. plant with ozone have been satisfactory and this treatment will be tried on larger scale.—*WPA*

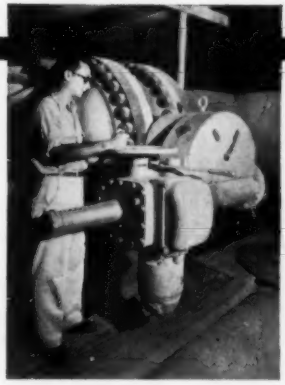
The Hydrogeological Basis of the Water Supply of Hesse. F. Michels & H. Updluft. Gas- u. Wasserfach (Ger.), **96**:301 ('55). After general outline of geology of Hesse, authors give account of hydrogeological conditions in various sections of district with special reference to water supply from ground water storage basins and streams. Wells of water supply of Allendorf and geology of intake area are then described.—*WPA*

Ground Water of the Hungarian Basins. Results of the Countrywide Ground Water Cartography of 1950–55. A. Ronai. Ann. Hung. Geol. Inst., **46**:1 ('56). Study and observation of ground water is important in country such as Hungary where more than half of pop. drinks well water and agricultural production is vital. More than 90% of water works are based on ground water as well. Every major constr., as navigation or irrig. canals, is influenced by level variations and compn. of ground water. Hungary has semiarid climate and rather dense pop. (259 per sq. mi.). Industrialization is necessity but only few industries could be settled in or around towns of Great Plains (which compose large portion of present Hungary) because of water shortage. Geological survey and cartographical work was started in Hungary around 1860, but Great Plains were always neglected, preference being given to mountainous areas. Agricultural soil survey was made mostly on Great Plains. First geological map of Hungary was published by Louis Loczy Sr. in 1890 and last and revised edition of this map was edited by K. Papp in 1918. Civil engineers started more intensive ground water observation. S. Rohringer established series of ground water observation wells between Danube and Tisza rivers since 1923 and these wells form core of present statewide observed and registered observation well system. Hungarian State Railways, which has more than 1,000 wells, also carries out

(Continued on page 80 P&R)



new . . . valve operator



reduces water hammer

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Especially designed for water works systems, this operator provides rapid initial closing of the valve with slow final closure.

Controlled operation combined with careful construction insures the dependability of A-C butterfly valves.

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ALLIS-CHALMERS

(Continued from page 78 P&R)

observations in its wells. Since 1933, Hydrographic Institute handled and developed ground water observation wells and published collected data. In 1955, 2,146 such wells were registered and regularly observed. Hydrographic Institute also designed in 1950 first ground water maps of Great Plains showing depth of ground water table below grade, el. of ground water above sea level and magnitude of seasonal variation. Available data, however, were not sufficient for detailed representation. Geological Institute made new geological survey of country between 1950 and 1955 and included in this observation of ground water as well. During survey, 1,030,042 dug wells and 15,965 drilled deep wells were observed and located over area of about 30,000 sq. mi. Ground water research extended over 4 yrs. but results were reduced to single date on basis of continuously observed well grid system. Because simultaneous observation of more than 1,000,000 wells is practically impossible and—if executed—would be subject to many errors as well, it is believed that procedure used is sufficiently accurate for large-scale area mapping. Isohypses, (ground water table contour lines) for large area such as entire country cannot be constructed closer than 1 m. (3–4 ft) apart, and this distance absorbs great deal of adjusted ground water table variation. Although there are districts with annual ground water variation of 10–15 ft, on many areas ground water el. does not vary more than few in. annually. All wells were located on 1:25,000 scale maps, and water level, depth and temperature, type of lifting mechanism, and other data were noted. Also, geological maps and profiles were constructed and well data tabulated. On basis of maps and observations, ground water conditions of single regions composing Great Plains are described in detail. Generally, there were some interesting conclusions to draw. Great Plains encompass area of about 16,600 sq. mi. and, out of this area, about 8,900 sq. mi. are covered with impermeable clay or loess. It could be said that there is no ground water over large area of Great Plains—at least, not according to definition of ground water—because there is no free ground water table and first water under clay is mostly under artesian pressure. Strict definition of ground water had to be relaxed in order to deal coherently with findings of survey. This compromise—or better, generalization—was found as necessary expedient in several other countries as well. There is no direct relationship between height of ground water table and quant. of pptn. Local rain in most cases does not replenish ground water; percolation stops well above ground water table. Evapn. would be more on large areas than total annual pptn. Replenishment of ground water originates partly from geological deep water due to slow subsidence of plains, partly from surrounding mountainous areas which have much more pptn., and, finally, from local sources—especially snow. Rivers contribute little to replenishment of ground water. Long horizontal movement of ground water could be explained by underground crevices, fissures, and old river beds filled with coarse sediment. There must be underground net of communicating water systems, probably with erosions and ever changing flows and paths. During survey, water samples were taken and analyzed chemically from 1,094 wells. In addition, water anals. of State Railways and other anals. of Geological Institute were used for map which shows chem. compn. of ground water. It would be interesting to know why largest collection of information on wells was not used at all for this survey. State Hygienic Institute, which was founded with assistance of Rockfeller Foundation, collected data of wells since 1927 and executed, between 1927 and 1938, more than 60,000 chem. well water anals. This information—if still available—could give much broader basis for map showing chem. components of ground water. Survey report is written in Hungarian and has ample condensation in German and Russian. Several colored ground water maps are attached and 191 references are given. Date of publication is Dec. 10, 1956. Original is available at Engineering Societies Library, New York City.—*Ed.*

Source of Water for Leopoldville. E. Ugeux. Tech. Eau (Belg.), No. 101 ('55). Dischg. of textile mill wastes into river Lukuga, Belgian Congo, which is chief source of water for Leopoldville, causes serious

(Continued on page 82 P&R)

EASY TO INSTALL CUTTING-IN VALVES FOR BETTER CONTROL

MECHANICAL JOINT

M & H Cutting-In Valves and Cutting-In Sleeves have mechanical joints designed to work with various classes of cast iron pipe. By cutting a short section of correct length out of an existing pipe line, the Sleeve and Valve are easily installed by unskilled workmen. The Cutting-In Valve is the same design, construction and materials as M & H A.W.W.A., double disc gate valves, except for the mechanical joint and connections designed to work with various outside diameters of different classes of pipe. These valves are available with O-Ring seal or conventional stuffing box. Sizes, 4" through 12". Write or phone for details.

M&H VALVE AND FITTINGS COMPANY
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(Continued from page 80 P&R)

contamn. Water is treated by coagulation with aluminium sulfate, sand filtration, addn. of lime to adjust acidity, and disinfection with ozone. Water from Galiema bay is now being utilized to augment water supply. —*WPA*

The Caithness Regional Water Supply Scheme. W. A. R. Baker, W. M. Jollans, & J. N. Dale. Proc. Inst. Civil Engrs. (London), **5**:366 ('56). Detailed description is given, accompanied by diagrams and photographs, of design and constr. of scheme for supply of potable water to whole of County of Caithness, exclusive of Burgh of Wick. Pop. served is small but scattered, and method of procurement and efficient distr. of water over considerable distances presented unusual problems. Scheme involves raising of water level in loch Calder to provide requisite storage; only small proportion of water is used for domestic supply, greater part being used to provide hydroelectric power to operate scheme. Raw water is screened as it enters penstock to flow by gravity to pumping station and treatment plant at Hoy. Treatment consists of preliminary chlorination, coagulation with alumina, filtration on pressure filters, and postchlorination. Treated water is pumped to service reservoirs for distr.; only first phase of distr. system is completed. Distr. network and location of service reservoirs are shown on key plan of scheme. Chem. and bact. analys. of raw water from loch Calder are included in appendix.—*WPA*

The City of Nottingham Water Undertaking. J. Brit. Wtr. Wks. Assn., **38**:161 ('56). Historical background of Nottingham's water supply is reviewed from late 17th century, undertaking being acquired in 1880 by corporation from Nottingham Waterworks Company. Details of undertaking in 1955 are given. Supplies are obtained from 2 main sources, wells and boreholes in Bunter sandstone, and impounding reservoirs belonging to Derwent Valley Water Board

(Continued on page 84 P&R)

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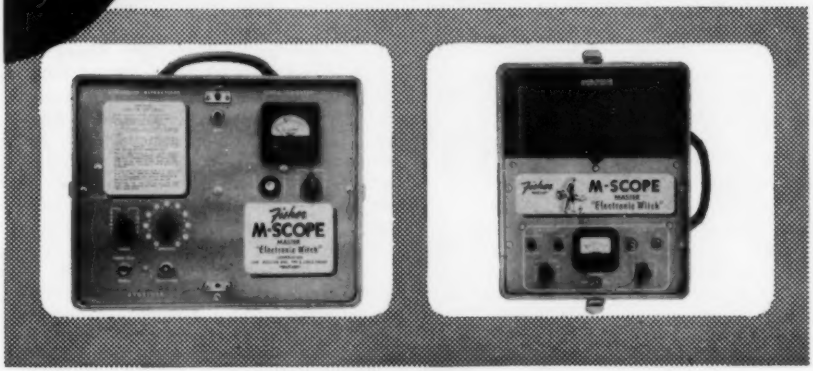

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(Continued from page 82 P&R)

situated in Derbyshire Peak district 50 mi. from city. Reliable daily yield from these sources is over 23 mgd, and undertaking supplies an avg. of 21.5 mgd to 522,000 persons in area of 262.6 sq. mi. Total available storage capac. is nearly 30 mil gal contained in 15 reservoirs; booster stations pump water to high-level districts. Brief description is given of pumping stations brought into use since 1880, and of projected developments.—*WPA*

Water Supply of Saint-Etienne. M. G. MIRASSOU. Tech. Eau (Belg.), No. 101 ('55). Author gives detailed historical account of development of present water supply of Saint-Etienne, France. Water is obtained from rivers Furan and Lignon and is treated by coagulation with aluminium sulfate, sedimentation, sand filtration and disinfection with chloramine.—*WPA*

One Hundred Years of Berlin's Water Supply, its Present Condition and Future Development. K. HUNERBERG. Gas- u. Wasserfach (Ger.), **97**:401 ('56). Account is given of development of Berlin's water supply from opening of first water works in 1856 and present condition and future requirements of supply are described. New intakes and extensions to treatment plants necessitated by division of Berlin in 1949 are described.—*WPA*

Malta's Water Problems. J. J. LEEMING. J. Inst. Water Engrs. (London), **10**:121 ('56). Island consists of layers of limestone and blue clay. Upper water table was used from 1610. Lower water table has been heavily drawn upon and sea water has come in. It is proposed to increase available water by storage.—*CA*

Water Supply in Scotland. M. Ross. J. Brit. Wtr. Wks. Assn., **37**:372 ('55). Topographical features and rainfall avgs for Scotland are described; avg annual rainfall ranges from 60 in. in mountainous west to 30 in. and less in eastern plains. Water resources are abundant, being derived from mountain streams which frequently feed lakes serving, in many cases, as impounding reservoirs, and from springs and wells. Quality of the water is excellent, varying in hardness from 50 ppm in west to 100–150 ppm in eastern dist. Some supplies from streams and impounding lakes require no treatment; supply from Lake Katrine and neighboring lakes for city of Glasgow is chlorinated only. Slow sand filters, developed in Scotland as long ago as 1804, are used extensively, although increased demand for water in recent years has led to adoption of rapid sand and pressure filters. Microstrainers have recently been installed by some authorities, including city of Edinburgh. Coagulation prior to filtration is necessary in catchment areas where discoloration from peat and bracken is troublesome. Disinfection, when required, is effected by chlorination. Water undertakings in Scotland are all administered by public authorities; 90% of population, including ⅔ of large rural population, receive piped water supplies, and avg daily consumption per head is 57 gal. Details are given of rating and water charges.—*WPA*

WELLS AND GROUND WATER

Artificial Replenishment of Underground Water in West Germany. C. R. BAIER. Aqua, No. 2, p. 5 ('55). Outline is given of development of practice of artificial replenishment of ground water in Ruhr valley, West Germany, and of methods employed at water works in Ruhr for abstracting ground water from recharged area. Construction and operation of infiltration basins lying parallel to river into which pold. river water is directed are described in detail; walls of basins are lined with concrete slabs and bottom gravel is covered with Rhine sand which is removed for cleaning as each basin empties. Filtration rates in basins, retention period in ground of recharge water, and phys., chem., and bact. characteristics of recharge water compared with those of ground water abstracted at water works are given, together with percentage of artificially recharged water used for water supplies. Artificial replenishment plant at Haltern, in western industrial area, using water from Stever R., is briefly described.—*WPA*

Ground Water Phenomena Related to Basin Recharge. P. BAUMANN. Proc. Am. Soc. Civil Engrs., No. 806 ('55). Ground water phenomena related to recharge of open and confined aquifers are reviewed, particularly in regard to practical application of

(Continued on page 86 P&R)

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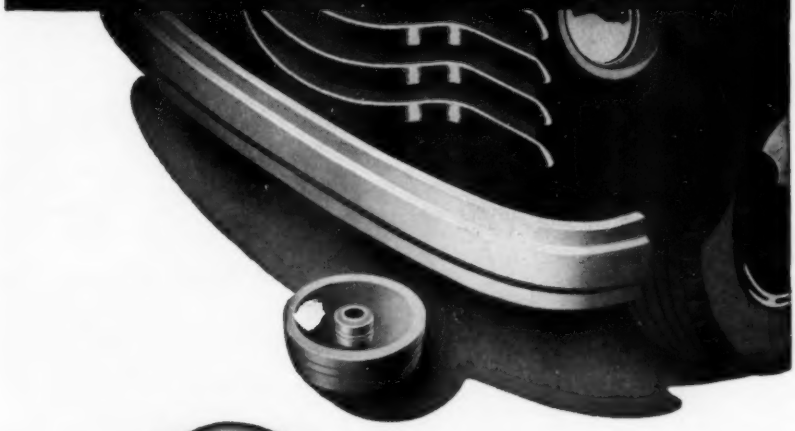

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(Continued from page 84 P&R)

previously developed theories for recharge of aquifers by means of seepage from spreading basins, whether in form of channels or roughly circular basins, and through injection wells. Schemes operated in Southern California are discussed. Injection through wells is primarily practiced in creating freshwater barrier to control salt water intrusion into ground water aquifers in the coastal plain.—*WPA*

Do Wells Fluctuating in Yield Reflect the Quality of Drinking Water in Chalk Mountains? J. STINI. Geol. u. Bauwes. (Aust.), **22**:69 ('56). After 10-yr. observation of wells situated in chalk mountains, in area around Innsbruck and Vienna, author obtained information concerning flow of waterways. It was found that there was little variation in qual. of water in wells of this type, but some danger may arise from entry of impurities. Qual. of water was evaluated on basis of source of supply. Terrain and wells adjacent to Muhlauer wells (which supply Innsbruck with drinking water of very good qual.) are discussed, and subsurface water sources and their composition are described.—*WPA*

Ground Water Can Alleviate Shortages. K. E. MOEHRL. Public Works, **86**:115 ('55). For future very favorable way of increasing water supplies is to make greater use of ground water. Author deals with choice of well site and construction of test wells. Certain general specifications are laid down for well construction. Underground storage can be utilized in many places where surface storage would be extremely costly. —*WPA*

The Status of Water Spreading for Ground Water Replenishment. L. SCHIFF. Trans. Am. Geophys. Union, **36**:1009 ('55). Methods for replenishment of ground water are reviewed, and strip and rotational system of spreading water, based on ratio of infiltration rate to percolation rate, is described.—*WPA*

Salt Water Encroachment Into Well Water in the Miami Area. E. M. RADER. Proc. Am. Soc. Civil Engrs., No. 669 ('55). Certain features of geography and hydrology of Miami area of southeast Florida are described to show how carrying out of drainage programs for agricultural development of area led to intrusion of sea water into wells used for municipal water supplies. Corrective measures were enforced by legislation to arrest encroachment of salt water further inland, and construction of check dams on rivers to prevent upstream movement of salt water. Projected flood control programs are described. Maps are appended showing extent of salt water encroachment in Miami area for years 1904, 1918, 1946 when it was at max., and diminishing of intrusion apparent by 1952.—*WPA*

The Rational Design of Ground Water Wells. Y. PETER. Civil Eng. (London), **50**:186 ('55). Author discusses practical application of existing formulae to design of wells, with particular reference to conditions in Israel.—*WPA*

Development of Public Ground Water Supplies in Massachusetts. R. M. SOULE. Sanitalk, **4**:5 ('56). Author gives illustrated description of tubular, drilled, and gravel-packed wells and comments on success of such installations in Mass. Importance of selection of site for construction of wells is stressed.—*WPA*

Interchange Connections Between Surface and Ground Water. F. LIPPERT. Wasserwirtsch. (Stuttgart), **46**:225 ('56). Author discusses importance of interchange between surface and ground waters, necessity for including ground waters in water legislation, and calcn. of flow-off, evapn. and rates of filtration, amt. of storage, and flow of ground water. Influence of geology of region and of river regulation, construction of dams, building, etc., on flow and storage of ground water, is described. Ground water conditions in Berlin area, use of artificial ground water obtained by seepage in Berlin and Rhine valley, and increasing importance of artificially supplemented ground water are discussed.—*WPA*

The Irrigation Aspects of Ground Water Development. H. R. MCDONALD. Proc. Am. Soc. Civil Engrs., No. 707 ('55). Author outlines methods for and potential advantages of coordinated use of ground water and surface-water storage in planning and operation of irrig. projects. In tracing historical development of irrig. in USA it is

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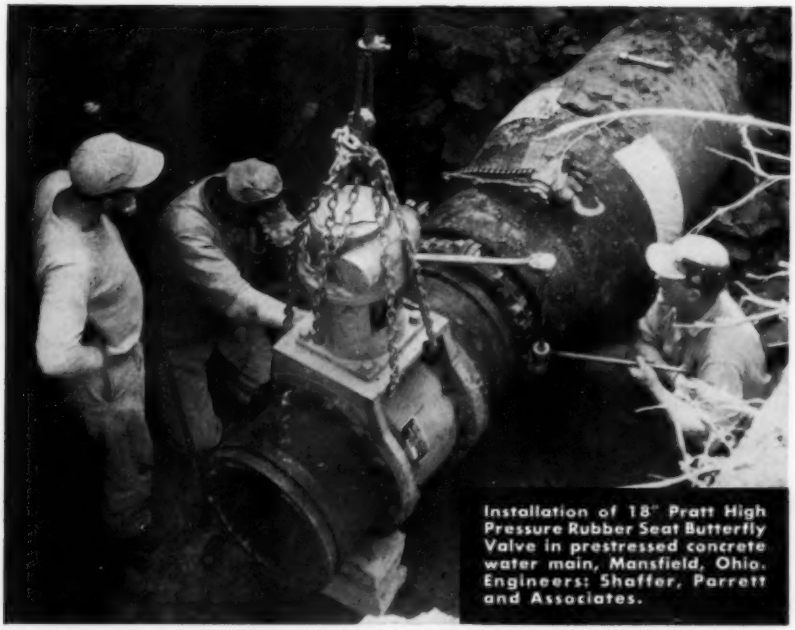

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The real test of a distribution valve is its ability to operate when needed. Valves in water distribution service are primarily emergency measures, normally left either open or closed for months, or even years. Yet, they must operate when needed, often to prevent serious property damage in the event of a broken water main.

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Filters

Basic filter parts include: the outside container, the bed of filter medium and the distribution and collection systems to provide a uniform flow through all parts of the bed. Flow rates average 2 to 3 gallons per minute per sq. ft. of bed area.

Filter beds are cleaned periodically by reversing the flow and increasing it to about 10 to 20 gpm per sq. ft. (backwashing). This lifts and swirls the sand, loosening the dirt and flushing it to waste.

Rotary surface washers with high-velocity water jets may be used to help break up the layer of dirt on top of the bed.

After backwashing, the first water through the filter (rinse water) also picks up some dirt and is run to waste.

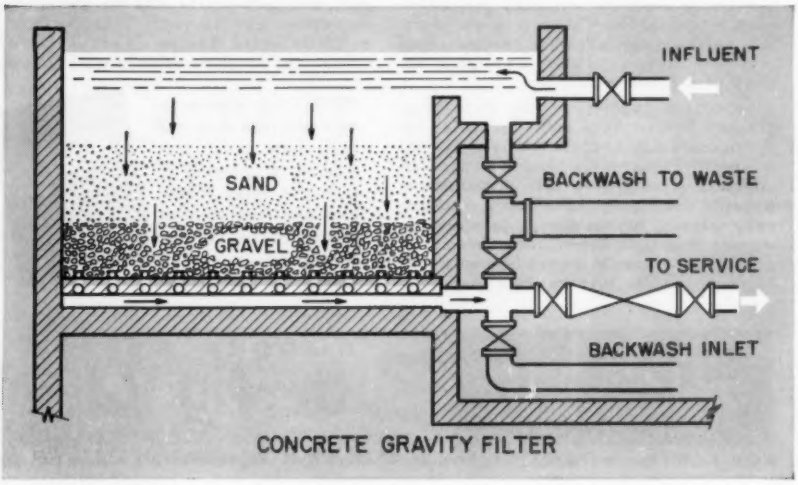
A "multiport valve" replaces 5 individual valves and reduces the number of valve manipulations for cleaning a filter from 10 to 3. It also indicates the cycle in progress and ensures proper sequence. Operation can be made completely automatic with hydraulically- or motor-operated valves controlled by meters, timers and float switches.

SAND FILTERS for removing dirt, precipitates, suspended solids

Sand filters simply "strain" the water as it flows downward through the filter bed. It is probably the oldest and most widely used method of water treatment.

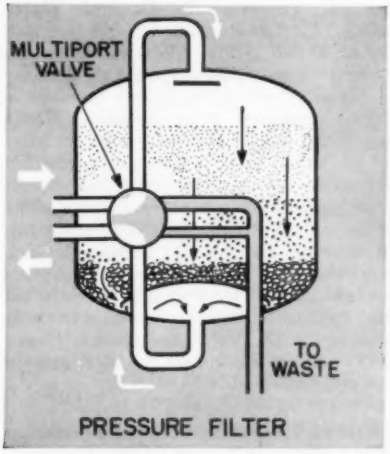
Gravity filters. Practically all large public water-supply plants include a series of gravity filters made of concrete for permanence and low maintenance cost. Sizes run up to 400 or 500 sq. ft. for each filter.

Chief difference among concrete gravity filters is the method of water collection under the filter bed. The false bottom system provides uniform collection but requires about 2 ft. extra filter height and is highest in cost. Header-lateral collection systems of steel pipe are lowest in cost but do not provide perfectly uniform collection and can corrode. There are also patented systems such as Permutit's *Monocrete*® system which uses collapsible forms for casting lateral ducts in the concrete itself. *Monocrete* ducts are oversize for



uniform collection and are corrosion-free since no metal is used. The cost is less than for false-bottom construction.

Steel-tank gravity filters cost less than concrete in small and medium sizes and are generally used in industrial plants. Wood-tank filters have low maintenance cost, but they are not practical for large sizes and not as attractive as painted metal. They are now used primarily where there is a metal shortage.

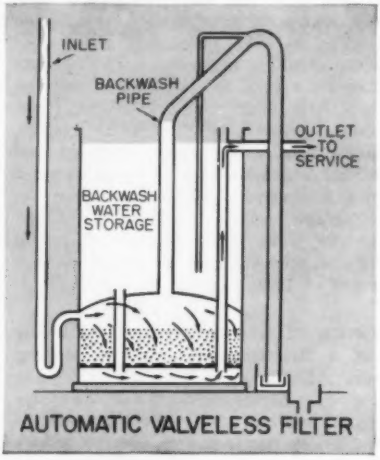


Pressure filters deliver an effluent under pressure, usually under 100 psi, to eliminate repumping. Since no water depth is required over the bed to provide pressure, these filters are smaller and lower in cost than gravity filters of the same capacity.

Vertical pressure filters are available to 12 ft. diam. with approx. 113 sq. ft. of bed area. Horizontal pressure filters provide large filter-bed areas, up to 200 sq. ft., at lowest tank cost but may not maintain as uniform bed conditions as vertical type.

Automatic Valveless Filters (gravity type) are a new Permutit development. They greatly reduce filter cost because they use no valves or flow controllers. They provide completely automatic, foolproof self-operation yet actually cost less than conventional manually-operated gravity filters. Sizes up to 12' diam. available.

When the suspended matter removed by the filter bed causes the pressure loss to reach a predetermined figure, backwashing starts automatically. At end of backwash, flow reverses automatically, and the backwash storage compartment is then filled with a brief rinse plus filtered water. Filtered water then passes to service through a separate outlet.



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Manganese zeolite oxidizes and removes moderate amounts of iron and manganese, also hydrogen sulphide, chief cause of "rotten egg" odor and sulphur taste. It is regenerated with potassium permanganate.

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(*Continued from page 86 P&R*)

stated that estd. use for this purpose was, in 1950, 44.2% of total water consumption and 50.2%, in 1945, of ground water consumption. Outline is given of developments in economic use of ground water for irrig. in Calif., Ariz., Tex., Colo., and other areas. General principles of ground water storage, discharge, and recharge are discussed and paper illustrates advantages of ground water pumping to reduce losses, to prevent or reduce drainage problems, and to irrig. addnl. land where water is of suitable qual. and aquifer characteristics are favorable for development of large-capacity wells.—*WPA*

Evaluation of Ground Waters With the Aid of a Biological Method of Drying Curves. M. PENKA. Folia Biol. (Arg.), 2:100 ('56). Method of detn. of conditions of retardation and stoppage of growth of plants (wheat, flax), and of plotting results graphically, is used for estn. of content of ground waters. Growth retardation begins at point at which freely moving capillary waters are absent; stoppage of growth occurs at point at which water-retaining forces in soil rise beyond above point. Growth retardation is best index of water defect. —*CA*

The Quality of Ground Water Estimated From Electric Resistivity Logs. W. A. PRYOR. Illinois State Geol. Survey Circ. 215 ('56). Resistivity of ground water from 94 wells in Pennsylvanian sandstone in Illinois Basin is calcd. from elec. well logs. Resistivity of drilling fluids and temp. of formation are taken into account. For extremely low or high contents of Cl and total solids, the concns. computed from resistivity logs differ markedly from chem. anals. For moderate ion concns. method is in fair agreement with chem. detns.—*CA*

Methods of Distinguishing Sea Ground Water From Hydrothermal Water. J. C. SCHOFIELD. New Zealand J. Sci. Technol., 37B:597 ('56). Ionic changes resulting from mixing of connate sea water with sediments and ground water will cause an anal. similar to that of a mixt. of ground water with an alk. hydrothermal water. Since the Cl^- does not react with sediment, sea water may be suspected when ratio of Σ cations to equivs. of Cl^- approximate that of sea water, 1:1.1. Percentage of sea water is $100(a-b)/c$, where $a = Cl^-$ content of sea ground water mixt., $b =$ the Cl^- content of local ground water, and $c =$ the Cl^- content of sea water. Ratio of Cl^- to Br^- in sea water is fairly consistent at about 300, while in hydrothermal waters it varies from 129 to 834. Sea water has Cl^-/Mg^{++} ratio in range of 11–30, while this ratio for hydrothermal waters is in range $37-\infty$.—*CA*

Chemical Processes in Ground Water Wells. L. GERB. Gas- u. Wasserfach (Ger.), 97:607 ('56). Waters contg. no dissolved O will dissolve min. amt. of Fe and deposit it as FeOH (ocher formation) on filter pipe and other conduits. These deposits can be removed with acid. In presence of larger amts. of O attack may be much more severe, with pitting and deposition of such heavy ocher deposits that filter pipe is clogged. Under these conditions, acid cleaning may lead to failure of pipes. Surprising thing is that many of these pipes have held up well for long periods—in other cases sudden failures occurred even with waters low in O. Veloc. and position (vertical or horizontal) appear to play role in these differences.—*CA*

Conditions Responsible for the Formation of Underground Waters of the Chlorine-Sodium-Calcium Type. S. Z. SAIDAKOVSKII, V. G. TKACHUK, & S. M. TSVIK. Gidrokhim. Materialy (USSR), 23:97 ('55). Theories advanced in explanation of formation of underground waters of Cl-Na-Ca type are discussed. One theory assumes that formation is due to cation-exchange between sea water and water-absorbing complex of certain rocky beds contg. occluded water, as found near oil wells. Under lab. conditions it was shown that appearance of $CaCl_2$ in underground waters is result of interaction between their Na content and Ca of occluded waters of rocks and that this process can take place at any distance from surface provided saline waters circulate through sandy clay strata contg. complexes of sufficient absorbency and enough Ca ions. Formation of $CaCl_2$ requires presence of 500–700 mg/l. of Cl ions. Waters do not have to be of oceanic origin to form Cl-Na-Ca type. When underground waters circulate through salt deposits they react in same ways as waters of oceanic origin. Best conditions for formation of salts of Cl-Na-Ca type are underground waters too deep to come into contact with surface fresh-water basins.—*CA*

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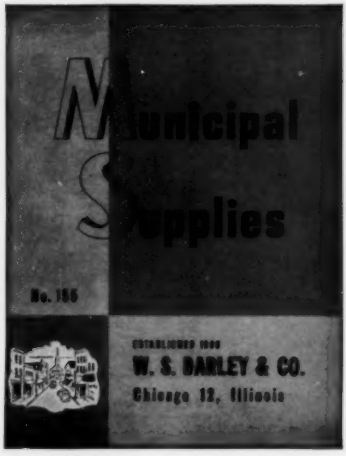
(Continued from page 62 P&R)

Herbert C. Clare, sanitary engineer in charge, Pacific Northwest Office, USPHS, has been named chairman of the Columbia Basin Inter Agency Committee, succeeding Brig. Gen. L. H. Foote of the US Army Corps of Engineers. In his new position, Mr. Clare will be assisted by Jerome H. Svore as executive secretary and chairman of the executive subcommittee. Mr. Svore, chief sanitary engineer, North Dakota Dept. of Health, was called to active duty with the USPHS to undertake this assignment.

George W. Kelsey, vice-president of B-I-F Industries, Inc., and president of its Builders-Providence Div., served as general chairman of the National Resources Conference recently held in Providence, R.I. The conference was one of a series being conducted in key cities by a team of officers representing the Industrial College of the Armed Forces. Its primary objectives were to emphasize the relationship between the nation's economy and national power and the need for cooperation between military and civilian leaders.

Haven Emerson, member of the New York City Board of Health and former head of the Columbia University School of Public Health, died May 21, 1957, at the age of 82. Born in New York City in 1874, he received an AB degree from Harvard in 1896, an AM from Columbia in 1899, and an MD from Columbia's College of

(Continued on page 96 P&R)



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LEAK CLAMPS
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Carson glands and bolts made of corrosion-resistant C-I-60 cast iron—last as long as cast iron pipe. Glands accommodate variations in pipe dimensions, insure uniform compression of rubber gasket.

Write for information

H. Y. CARSON COMPANY
1221 Pinson St. Birmingham, Ala.

Here's How KENNEDY'S A.W.W.A. Valves Give You Longer, Low Cost Service . . .

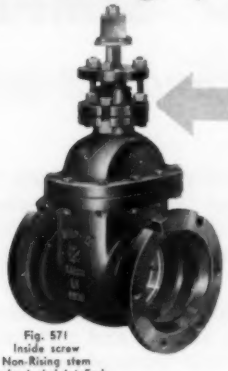
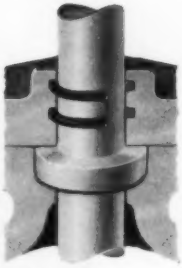


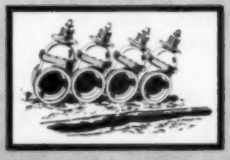
Fig. 571
Inside screw
Non-Rising stem
Mechanical Joint Ends

O-RINGS provide excellent seal, preventing any binding of the stem and resulting in very easy valve operation.



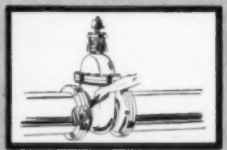
Mechanical joint ends save time and labor on installation.

Installation suggestions for better valve service



Prior to installation on the job, valves should be kept tightly closed and covered to prevent foreign matter such as sand and grit from damaging seat faces.

Clean pipe thoroughly before installing valves since mill scale, dirt and chips will cut valve seats. Install A.W.W.A. valves in closed position.



When tightening bolts of flanged valves, install bolts at 180° and tighten each bolt at opposite sides of the diameter a little at a time instead of tightening one fully, then moving to next. This prevents undue stress and distortion.

These valves, designed for use in municipal water works systems, conform to A.W.W.A. specifications. While A.W.W.A. specifications cover only bell end and flanged non-rising-stem valves, the KENNEDY line of A.W.W.A. standard gate valves also includes outside-screw-and-yoke valves and all regular pipe end connections.

In KENNEDY'S Hook-and-Wedge type disc mechanism, sticking or locking is prevented because one disc is released before the other. When valve is closing, the discs bearing the wedges and hooks descend until the port opening is completely covered. In final downward movement of the discs, the wedges act against correspondingly inclined surfaces in the backs of the discs so as to spread the discs apart and force them tightly against the seats. The operation is perfect with either disc toward the pressure.

• See for yourself how KENNEDY A. W. W. A. Valves can save you money. Get complete details in Bulletin 561 -- WRITE TODAY!

KENNEDY VALVE MFG. CO.

1604 E. WATER ST., ELMIRA, NEW YORK

VALVES • PIPE FITTINGS • FIRE HYDRANTS

• OFFICE AND WAREHOUSES IN NEW YORK, CHICAGO, SAN FRANCISCO, ATLANTA • SALES REPRESENTATIVES IN PRINCIPAL CITIES •

Liquid Alum Means

SIMPLE AND

. . . and a 3-year pay-off

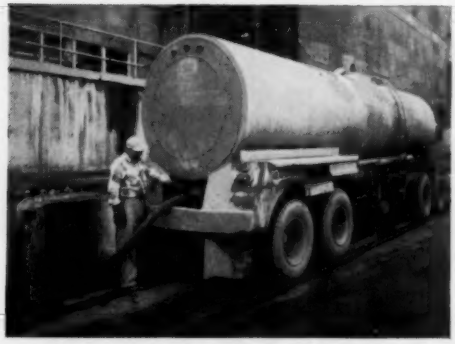
"We have been saving $17,000 a year at the South District Filtration Plant since August 1954, when we replaced our dry-feed system with a liquid alum installation. The change-over cost, we estimate, is to be fully paid off in three years of operation.

"In addition to the monetary saving, we find the liquid alum system to be cleaner, simpler and certainly more dependable. There is no stratification of the liquid alum in storage or feed tanks, and easily controlled metering eliminates the overfeeding and underfeeding experienced with dry alum handling equipment.

"Our operating engineers and technical staff are well pleased with *all* aspects of the new system."

You may want to take advantage of the lower cost of liquid alum—or put your water treating on a cleaner, more efficient basis—or both. A Cyanamid representative can help you determine the annual savings in purchasing liquid alum. He can also advise you on the simple installation that will make your water-treating system cleaner and more efficient . . . capable of continual dependable performance with the minimum of supervision.

Benefit from Cyanamid's extensive experience in the conversion of dry-feed systems to liquid. Request a *Liquid Alum Survey*. Call or write your nearest Cyanamid Office.



"Liquid alum flows by gravity from rubber-lined tank trucks to our storage tanks. Our supervision is not required."

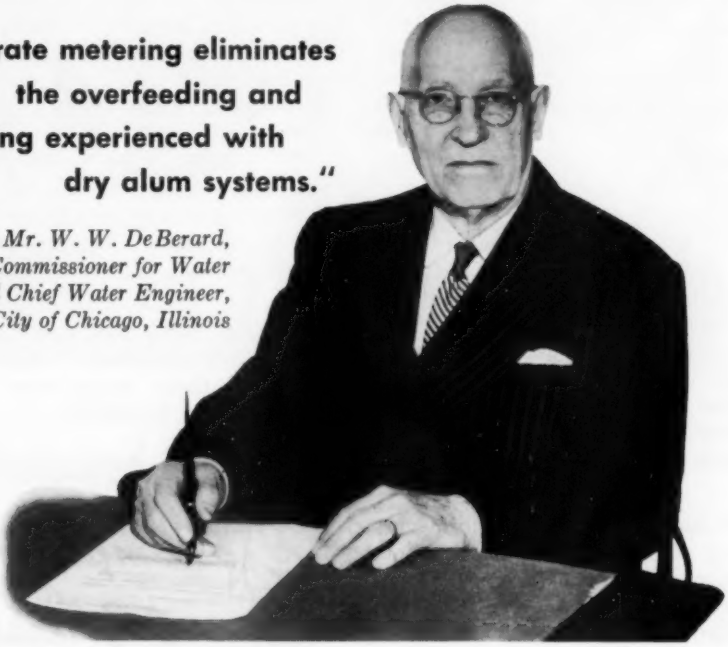
"The simplicity and neatness of our new liquid s tem (right) is evident by comparison with the dry-feed system (left)."

DEPENDABLE OPERATION

on installation at Chicago

"Accurate metering eliminates the overfeeding and underfeeding experienced with dry alum systems."

—says Mr. W. W. DeBerard, Deputy Commissioner for Water and Chief Water Engineer, City of Chicago, Illinois



A needle valve and rotameter give accurate control of liquid alum feed, with a pengraph maintaining permanent record. Our old dilution system is used."

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HEAVY CHEMICALS DEPARTMENT
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Toronto and Montreal

(Continued from page 92 P&R)

Physicians & Surgeons the same year. Dr. Emerson joined the New York City health department in 1914 as deputy commissioner and served as commissioner in 1916–17. In World War I he was chief epidemiologist to the A.E.F. in France. Beginning in 1920 he conducted a long series of health surveys of American cities. He joined the Columbia faculty in 1932, retiring in 1940. In 1938 he was appointed to an 8-year term as a member of the New York City Board of Health and later was reappointed twice, most recently in 1954.

Dr. Emerson was largely responsible for the compilation of a "Standard Classified Nomenclature of Disease," an authoritative reference work in the field. He was a member of numerous national and international bodies concerned with public health and was a former president of American Public Health Assn.

William C. Sherwood, former secretary of the Hersey Mfg. Co., South Boston, Mass., died Jun. 9, 1957. He was 78. A native of Jersey City, N.J., he formerly served on the Civil Service Commission there. He had been associated with the Hersey Company since 1900, retiring last year.

Mr. Sherwood represented his firm in AWWA for many years and was an AWWA director, as well as a former president of the Water & Sewage Works Manufacturers Assn. Other professional societies to which he belonged included the Inter-American Association of Sanitary Engineers, American Ordnance Assn., and National Assn. of Corrosion Engineers.

Herman L. Shiflett, general manager, Water Works Board, Birmingham, Ala., died suddenly Jun. 14, 1957, of a heart attack at the age of 58. He was born in Rome, Ga., but his career took him to almost every state in the nation. He served in various capacities with the public water works supply system of the American Water Works Co. from 1928 through 1956 and was assistant division manager in Philadelphia when he left to join the Birmingham water works on Mar. 1, 1956.

Mr. Shiflett represented the Birmingham Water Works Board in AWWA and was also a member of the Birmingham Chamber of Commerce Industrial Water Committee.

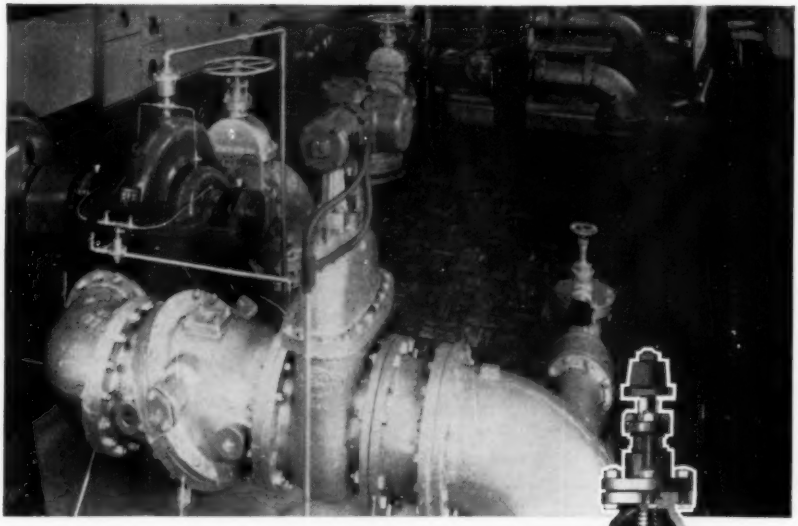
Sedalia, Mo., has purchased the General Waterworks Corp. water properties there, which have a gross book value of $2,800,000.

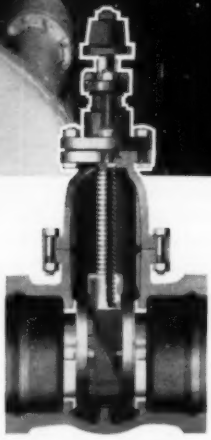
Employment Information

Classified ads will be accepted only for "Positions Available" or "Positions Wanted." Rate: $1.50 per line (minimum $5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

Positions Available

ENGINEER: Good opportunity for experienced distribution engineer with a large privately owned Water Company. College training desired but not a requisite. Please send resume including educational background and practical experience to Mr. George H. Dann, Exec. Vice President, Phila. Suburban Water Co., 762 Lancaster Ave., Bryn Mawr, Pa.





This cutaway shows the Darling principle that assures uniform wear distribution, automatic seating compensation, prolonged tight closure and unusual valve life.

Sustained top performance

. . . a **DARLING** gate valve bonus!

HERE'S a point to bear in mind about the Darling valves installed in this fine new water pumping station at Tonawanda, N. Y. As in so many other applications everywhere, those Darling gate valves are bound to grow old, in years, but they'll *stay young* in performance!

It's the precision manufacture and the Darling fully revolving double disc parallel seat principle that always makes a world of difference! It means prolonged tight closure, avoidance of trouble and low maintenance through the years.

Look into these facts . . . and make Darling gate valves *your* first choice. They are available in types, sizes and with the proper ends for virtually all requirements. Send for Bulletin 5403.

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Manufactured in Canada by The Canada Valve & Hydrant Co., Ltd., Brantford 7, Ont.

DARLING VALVES

Section Meetings

Pennsylvania Section: The ninth annual meeting of the Pennsylvania Section was held at Bedford Springs Hotel, Bedford, Jun. 12–14, 1957. The official registration was 255 men and women. The technical program was one of the best ever presented to the Section. [A list of papers and authors will appear in the December 1957 issue.]

One of the highlights of the meeting was a demonstration of procedure in a typical rate case. J. H. Eisaman of the State Public Utility Commission took the role of presiding examiner; counsel for the respondent was N. T. Hays, of Morgan, Lewis & Bockius, Philadelphia; for the complainant, David Stahl, assistant city solicitor, Pittsburgh; and for the commission, Charles E. Thomas, of Hull, Leiby & Metzger, Harrisburg. Witnesses for the respondent were J. N. Zimmerman, of Morris Knowles, Inc., Pittsburgh; Jack H. Workmaster, of the Pittsburgh Chapter of ASA; and Roger A. McShea Jr., of the Scranton–Spring Brook Water Service Co., Wilkes-Barre. For the city, witnesses were George D. Porter, Equitable Gas Co., Pittsburgh; G. V. Gustafson, Wilkinsburg-Penn Joint Water Authority, Pittsburgh; and Marvin B. Miller, Duquesne Light Co., Pittsburgh. C. Radford Berry, of the State Public Utility Commission, Harrisburg, appeared as a witness for the commission. The moderator was John W. Guilday, of Morris Knowles, Inc., Pittsburgh, and the hearing reporter was Joseph F. O'Grady, of Rockwell Mfg. Co., Pittsburgh.

At the business session the following officers were selected for the ensuing year: chairman—G. E. Arnold, Philadelphia; vice-chairman—J. R. Harvey, Meadville; trustee—S. S. Baxter, Philadelphia; and secretary-treasurer—L. S. Morgan, Greensburg.

Naturally, not all was business and technical sessions. At the annual banquet Thursday night, Jun. 13, Jack Johnson and George Papesch of Erie were honored for their century of service with the water department at Erie [see this

(*Continued on page 100 P&R*)

ATTENTION Water Meter Repairmen!

***Patrick* COPPER AND BRASS DIP**

In Concentrate Form—For finished product add water

QUICK ACTING, RESTORES LUSTER TO COPPER, BRASS, AND BRONZE

12 containers of concentrate makes 12 gallons of C. and B. Dip, approximate weight 33 lbs. $28.20 prepaid. Net 30 days.

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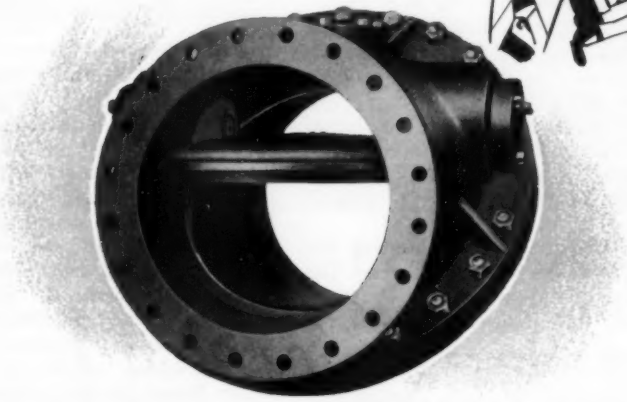
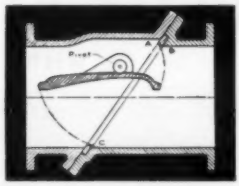
You have to see it to believe it...
(You Can't Hear It!)



CHAPMAN Tilting Disc Check Valve

It's the silent valve. No noise, no vibration, no fluttering. On usual piping arrangements you get no slamming with a Chapman Tilting Disc Check Valve. You get no banging to cause damage to system or valve . . . no grinding, scraping or wearing of either the disc or seat. Your maintenance costs go down to an unbelievable low which is really something to see and enjoy.

You can safely use these valves under tough operating conditions. You can order them in iron and steel . . . for handling fluids or gases under a wide range of pressures. You can get them fast. See our Catalog 30-A. Write for your copy today.



Look at this operational chart. When the flow is on, "airfoil" disc is held firmly against stops in the body. When the flow drops, disc balances quietly on whatever flow there is. When flow stops, disc drops quickly, quietly and firmly on special bevel seat. Note that sufficient space is designed around disc to cut down flow resistance.

The CHAPMAN Valve Manufacturing Co.
INDIAN ORCHARD, MASSACHUSETTS

Section Meetings

(Continued from page 98 P&R)

issue, p. 50 P&R]. Nominated for the Fuller Award was Col. Willard F. Rockwell.

The well attended cocktail hours, where old friends were met and new ones made, were sponsored by WSWMA. The ladies, 70 in all, enjoyed their own program of activities while the men attended the technical sessions and then joined their men in some rare and unusual type of entertainment, including a "Coagulation Jamboree" in the form of an old-fashioned square dance in the barn, with suitable accouterments. The setting at Bedford Springs Hotel is picturesque and one cannot help enjoy himself at such a place, with a well planned program of activities.

Those who attended the meeting felt that this was indeed the best yet. The symposium on "Water Works Practice" by the various participants was exceptionally well received, owing to the high quality of the speakers and of the material presented. The "Typical Rate Case" previously described had an excellent reception, too, being informatively and interestingly presented, with some levity not generally encountered in such proceedings.

L. S. MORGAN
Secretary-Treasurer

New York Section: The New York Section held its annual spring meeting at the Mark Twain Hotel, Elmira, Apr. 10–12, 1957. The total registration was 292. The technical program covered such topics as civil defense funds and property available to water departments, distribution storage, aerial surveys, effect of synthetic detergents on chlorination, and water works personnel problems. [A list of papers and authors will appear in the December 1957 JOURNAL.]

Social events included a luncheon at which Mayor Edward Mooers welcomed the Section to Elmira, as well as a Club Room get-together and a pre-Banquet cocktail hour sponsored by WSWMA. At the Banquet, held Thursday evening, Apr. 11, Reeves Newsom, of Scarsdale, received the nomination for the Fuller Award, and Life Membership certificates were presented to N. F. Fenn, Frank J. Keis, Frank C. Amsbary Jr., and Alexander Russell. A special award from the Elmira Water Board was presented to James M. Caird, consultant to the board for the past 60 years. Frank D. Behan turned over the Section chairmanship to L. J. Griswold. Other new officers elected were J. M. Diven, vice-chairman, and Clarence W. Taylor, trustee. The evening ended with a beer party which featured singing by the Elmira College "Twain Tones."

Thanks and appreciation go to the city of Elmira and to the Elmira Water Board for their help and cooperation in making the meeting so successful.

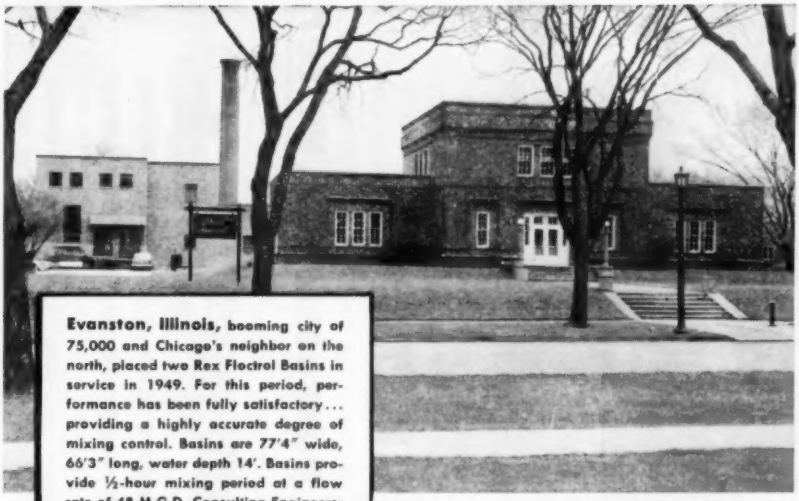
KIMBALL BLANCHARD
Secretary-Treasurer

SAVE MONEY
on
METER REPAIRS
with

- ***Memphis Slot Inserts*** **and new thrust rollers, for 5/8″–2″ water meters**
- **Stainless steel disc sleeves, for 1″, 1 1/2″, and 2″ water meters, and**
- ***Twist-On Covers,*** **for 5/8″ water meters!**

For further information and *free 5/8″ samples,* address

METER SPECIALTY CO.
Sterick Bldg. Memphis 3, Tenn.



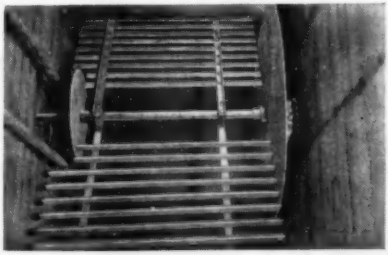
Evanston, Illinois, booming city of 75,000 and Chicago's neighbor on the north, placed two Rex Floctrol Basins in service in 1949. For this period, performance has been fully satisfactory... providing a highly accurate degree of mixing control. Basins are 77'4" wide, 66'3" long, water depth 14'. Basins provide ½-hour mixing period at a flow rate of 48 M.G.D. Consulting Engineers: Alvord, Burdick & Howson, Chicago; Superintendent of Evanston Waterworks, Horace Frye.

EVANSTON marks 8 years efficient service with REX® FLOCTROL

Eight years actually is a short period in the long, dependable service life of Rex Floctrol. Equally important as long life is the accurate mixing control provided by Floctrol...with its outstanding advantages in economical, efficient performance. Minimum amount of chemicals is required...a large, readily settleable floc is produced..."short circuiting" is eliminated. The results: smaller basins can be used for a given volume...construction and operating costs reduced.

The Rex Floctrol is designed with a unique combination of mixing paddles, rotating baffles and fixed partition walls that assure full utilization of tank volume. The balanced proportions of these units assure most efficient mixing, proper flow distribution, and accurate control of mixing.

Ask for a copy of Bulletin No. 53-76, "Flocculation Equipment." CHAIN Belt Company, 4609 W. Greenfield Ave., Milwaukee 1, Wis.



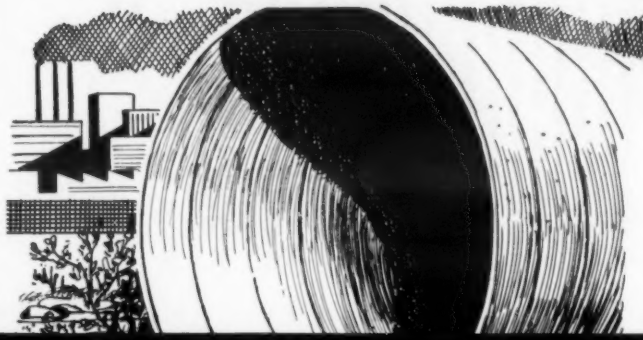
View of typical Floctrol chamber showing arrangement of paddle, rotating baffles and fixed partition walls.

CHAIN BELT

Milwaukee 1, Wis.

Men and property guarded

but how about our most precious possession . . . water?



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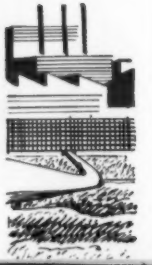
Safety costs millions — and they're dollars well spent. But reckless spending of water can destroy any community. If the situation is not already critical in your area, chances are in a few years it will be. Take the first logical step now toward water conservation, with Badger



water cost, sharply reduce waste and build water revenue

logical step now toward water conservation, with Badger

water cost, sharply reduce waste and build water revenue.

Badger disc, turbine and compound meters are adaptable to all local needs and water conditions. An example of Badger leadership is their exclusive compound meter which handles fluctuating water demands of factories, schools, theatres and apartment buildings—wherever the rate of flow varies through the day. Badger compound meters, like all other water meters in this complete line, assure maximum utility with full honest revenue.

Act now for your community's welfare and progress—new building, business and industry — all assured through adequate water, conserved by Badger meters. Write for literature or to arrange consultation with a Badger Meter representative.

Outstanding disc, turbine and compound meters — ⅝" through 12" — precision engineered for lasting service.

Water is vital

Badger Meters have conserved it better for over 50 years.

Badger Water Meters

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Milwaukee 45, Wisconsin • *OFFICES IN PRINCIPAL CITIES*

NEW MEMBERS

Applications received Jun. 1–30, 1957

Archer, John Gillies, Engr., Dept. of National Defense, Bldg. 16, Victoria Island, Ottawa, Ont. (Jul. '57)

Argonne National Lab., Remo Puricelli, Plant Services Supervisor, Box 299, Lemont, Ill. (Corp. M. Jul. '57) *MRPD*

Baigas, Joseph F., Jr., Partner, Reddy, Evans, Baigas & Segrave, Box 11076, Charlotte 9, N.C. (Jul. '57) *RPD*

Bates, Charles A., Office Mgr., Stamford Water Co., 103 Summer St., Stamford, Conn. (Jul. '57) *M*

Battershill, J. W., Engr., 755 Henderson Hwy., East Kildonan, Man. (Jul. '57)

Berry, W. W., Dist. Repr., Worthington-Gamon Meter Div., Box 554, Killeen, Tex. (Jul. '57)

Binnie, Geoffrey M., Partner, Binnie, Deacon & Gourley, Artillery House, Artillery Row, Westminster S.W. 1, England (Jul. '57)

Bobkoff, Kenneth Bruce, Salesman, United Concrete Pipe Corp., Box 10283, Industrial Sta., Dallas, Tex. (Jul. '57) *D*

Bohannan, Jerry Ray, Civ. Engr., Wilson & Co., Box 3305, Albuquerque, N.M. (Jul. '57) *P*

Bombard, Douglas J., Chief Water Plant Operator, Water Dept., 220 Main St., Hudson Falls, N.Y. (Jul. '57) *PD*

Boux, J. Francis, Pres., Tru-Flow Pipe Ltd., 790 St. Joseph St., St. Boniface, Man. (Jul. '57)

Bowdler, Robert G., Sales Engr., Salem-Brosius, Inc., Carnegie, Pa. (Jul. '57) *P*

Brand, George C., Supt., Water & Gas Dept., Tallahassee, Fla. (Jul. '57) *MD*

Brown, Martin M., Asst. Chief Engr., Associated Reciprocal Exchanges, 2 Park Ave., New York 16, N.Y. (Jul. '57) *MD*

Bruggink, Raymond, Jr., City Engr., 209 City Hall, Grand Rapids, Mich. (Jul. '57) *RP*

Campbell, M. S., Bacteriologist, Bureau of Labs., State Bd. of Health, 1330 W. Michigan St., Indianapolis 7, Ind. (Jul. '57) *P*

Carey, William, Supt., Water Works, Lake & Tyler St., Laporte, Ind. (Jul. '57) *MRPD*

Chlebicki, George J., Cons. Engr., George J. Chlebicki & Assocs., 15304 Center Ave., Harvey, Ill. (Jul. '57) *MRPD*

Cleland, M. C., Sales Engr., Dresser Mfg. Div., Dresser Industries, Republic National Bank Bldg., Dallas, Tex. (Jul. '57) *MD*

Clendenen, Frank Byron, Asst. Prof. of Civ. Eng., Univ. of California, Berkeley, Calif. (Jul. '57) *R*

Codolute, John; *see* Garden City Park (N.Y.) Water Dist.

Conway, City of, Robert S. Winfield, City Engr., 1003—3rd Ave., Conway, S.C. (Corp. M. Jul. '57) *MD*

Cover, Franklin H., Mech. Engr. of Design, Utilities Dept., Utilities Eng. Div., 607 Lincoln Bldg., Cleveland, Ohio (Jul. '57) *MD*

(*Continued on page 106 P&R*)

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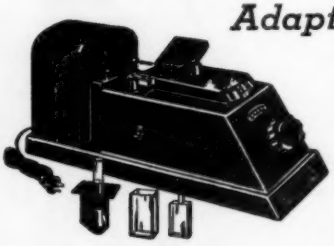

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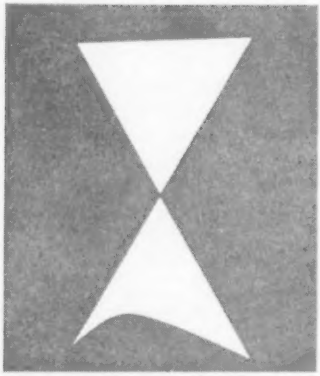

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Dave, Jaydev M., Designing Engr., Anderson & Assoc., 1509 Pioneer Bldg., St. Paul 1, Minn. (Jul. '57) *MPD*

Davenport, John E., Secy., Stamford Water Co., 103 Summer St., Stamford, Conn. (Jul. '57) *M*

Deas, Eugene I., Sales Engr., Frank Howell Co., 9 E. Cary St., Richmond, Va. (Jul. '57) *PD*

Denison Utilities, G. W. Wright, Supt., Denison, Iowa (Munic. Sv. Sub. Jul. '57) *MRPD*

Dougherty, Harry A.; *see* Fisher Tank Co.

Estopinal, Eugene I., Parish Engr., St. Bernard Parish Police Jury, 204 Court House, Chalmette, La. (Jul. '57) *RP*

Fisher Tank Co., Harry A. Dougherty, Mgr. of Sales, 3rd & Booth Sts., Chester, Pa. (Assoc. M. Jul. '57)

Fitzgerald, N. A., Chief Engr., Ideal Petroleum Co., Inc., 8555 Artesia St., Bellflower, Calif. (Jul. '57) *MD*

Fulcher, Albert Lee, Supt., Water Works, Cumberland, Ky. (Jul. '57) *MPD*

Galloway, Sherman Elsworth, Geologist, Water Resources & Development Sec., Tech. Div., Office of State Engr., Box 810, Roswell, N.M. (Jul. '57) *R*

Garber, Jack D., Sales Engr., Johns-Manville Sales Corp., 507 Dooly Bldg., Salt Lake City, Utah (Jul. '57) *D*

Garden City Park Water Dist., John Codolute, 2264 Jericho Tpke, Garden City Park, N.Y. (Jul. '57) *RD*

Gassie, Donald V., Mgr., Utilities System, Box 208, Lafayette, La. (Jul. '57) *M*

Glover, Walter H., Comr., Water Works, Joiner, Ark. (Jul. '57) *PD*

Gould, Matthew, Chemist, Hagan Corp. Ltd., 185 Eileen Ave., Toronto 9, Ont. (Jul. '57)

Grant, V. W., Sales Service Engr., Bailey Meter Co., 9621 W. 16th St., St. Louis Park, Minn. (Jul. '57) *PD*

Hamilton Square Water Co., A. F. Hauptfuhrer, Pres., 51 Park Ave., Hamilton Square, N.J. (Corp. M. Jul. '57) *MRD*

Hauptfuhrer, A. F.; *see* Hamilton Square (N.J.) Water Co.

Ilienberger, G. M.; *see* Morgan Steel Products, Inc.

Jones, Luther W., Water Supt., Box 575, Andrews, Tex. (Jul. '57) *D*

Jordon, Edward Clarence, Pres., Edward C. Jordan, Inc., 379½ Congress St., Portland, Me. (Jul. '57) *MP*

Kengle, Lansford Franklin, City Mgr., Lincoln, Calif. (Jul. '57) *MPD*

Kreitman, Abe, Geologist, C. W. Lauman Co., Inc., Box 235, Hicksville, N.Y. (Jul. '57) *RP*

Linde, Richard I., Asst. Tech. Director, Heavy Chemicals Dept., American Cyanamid Co., 30 Rockefeller Plaza, New York 20, N.Y. (Jul. '57) *P*

Lowe, Clement Proctor, Mgr. for Atlantic Provinces, Canadian-British Eng. Consultants, 513 Barrington St., Halifax, N.S. (Jul. '57)

Lynch, Emory E.; *see* Trojan Steel Co.

McDermott, Thomas P., Field Repr., Electro Rust-Proofing Corp., 9 Hermosa Dr., Homewood, Ala. (Jul. '57) *MPD*

Meneses Hoyos, Roberto, Apdo. Postal 1416, Mexico 1, D.F., Mexico (Oct. '46)

Mian, Guillermo N., Physical Science Aide, Fena Water Treatment Plant Lab., US Navy Public Works Center, Guam, M.I. (Jul. '57) *MRPD*

Miles, Morris A., Supervisor of Water Treatment, Rock Island, Ill. (Jul. '57) *MP*

Moore, Carl Edward, Assoc. Prof., Loyola Univ., 6525 N. Sheridan Rd., Chicago, Ill. (Jul. '57)

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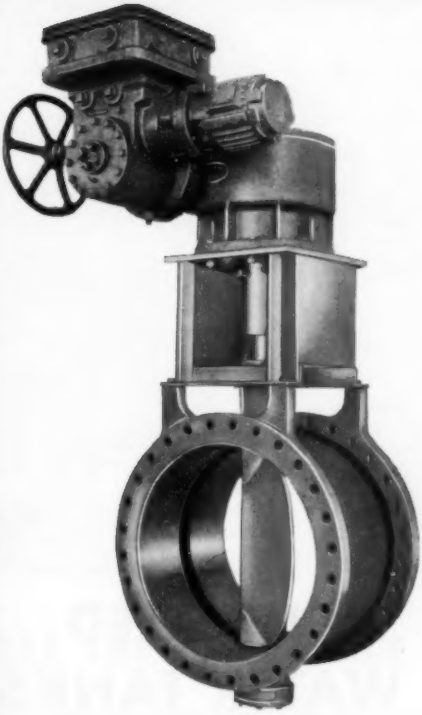

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Neubauer, Walter K., Assoc. Engr., O'Brien & Gere, 400 E. Genesee St., Syracuse, N.Y. (Jul. '57) *RPD*

Patterson, Frank A., Sales & Application Engr., Honeywell Controls Ltd., 6277 Upper Lachine Rd., Montreal, Que. (Jul. '57)

Posey, Chesley Johnston, Prof. of Hydr., Dept. of Civ. Eng., Univ. of Iowa, Iowa City, Iowa (Jul. '57) *RD*

Puricelli, Remo; *see* Argonne National Lab.

Reins, Robert L., Vice-Pres., Heningson, Durham & Richardson, 2962 Horney, Omaha, Neb. (Jul. '57) *PD*

Russell, Don A., Office Mgr., Utilities Dept., Tyler Pipe & Foundry Co., Box 2027, Tyler, Tex. (Jul. '57) *D*

Salazar, Robert J., Sales Repr., Pipe Div., Johns-Manville Sales Corp., 1755 Glenarm Pl., Denver 2, Colo. (Jul. '57) *D*

Savannah Public Utilities, Halle J. Shaw, Supt., Savannah, Tenn. (Munic. Sv. Sub. Jul. '57) *MRPD*

Schlimmeyer, Wilbert, Student, Rutgers Univ., 236—1st St., Dunellon, N.J. (Jr. M. Jul. '57)

Shaw, Halle J.; *see* Savannah (Tenn.) Public Utilities

Shearer, David A., Sales-Service Engr., Bailey Meter Co., Ltd., 1980 Claremont Ave., Montreal 6, Que. (Jul. '57)

Skinner, Oren L., Supt., Water Dept., Box 406, Brookston, Ind. (Jul. '57) *MD*

Soukup, Albert V., Dist. San. Engr., Div. of Sanitation, State Board of Health, City Hall, Hays, Kan. (Jul. '57) *P*

Sullivan, D. N.; *see* West Coast Corrosion Eng. Corp.

Sveinbjornson, I. B., City Engr., City Offices, Yorkton, Sask. (Jul. '57)

Texarkana Water & Sewer Systems, W. J. Weems, Mgr., Box 295, Texarkana, Ark. (Corp. M. Jul. '57)

Thompson, William L., Chemist, West Penn Power Co., Springdale, Pa. (Jul. '57) *P*

Trojan Steel Co., Emory E. Lynch, Engr., Box 2426, Charleston 29, W. Va. (Assoc. M. Jul. '57)

Uehlein, F. J., Eastern Sales Mgr., W. E. Caldwell Co., 475—5th Ave., New York 17, N.Y. (Jul. '57)

Vanderhelden, John, Asst. Gen. Supt., Public Utilities Com., Dundas at Wellington St., London, Ont. (Jul. '57)

Veit, Howard C., Supt., Dist. System, Stamford Water Co., 103 Summer St., Stamford, Conn. (Jul. '57) *D*

Walker, Edward Albert, Chief, Bathing Place Unit, State Dept. of Health, Box 90, Harrisburg, Pa. (Jul. '57)

Webster, Alan, City Mgr., City Hall, Grand Forks, N.D. (Jul. '57) *M*

Weems, W. J.; *see* Texarkana (Ark.) Water & Sewer Systems

West Coast Corrosion Eng. Corp., D. N. Sullivan, Pres., 1112 E. Washington Ave., Santa Ana, Calif. (Assoc. M. Jul. '57)

Wheeler, Roy Alexander, Field Repr., Canada Valve & Hydrant Co., Ltd., Box 1007, Brantford, Ont. (Jul. '57) *D*

Winfield, Robert S.; *see* Conway (S.C.)

Winkler, W. Lee, Supt., Lake Maumelle Rte. 1, Roland, Ark. (Jul. '57) *RPD*

Wright, G. W.; *see* Denison (Iowa) Utilities

Zouzalik, Edward H., Mayor, Box 238, Flatonia, Tex. (Jul. '57) *MP*

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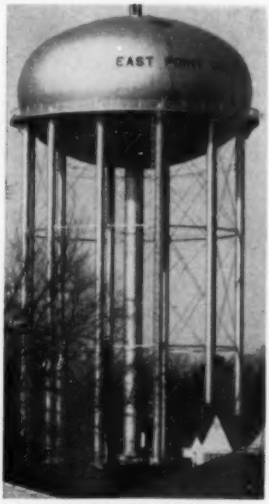

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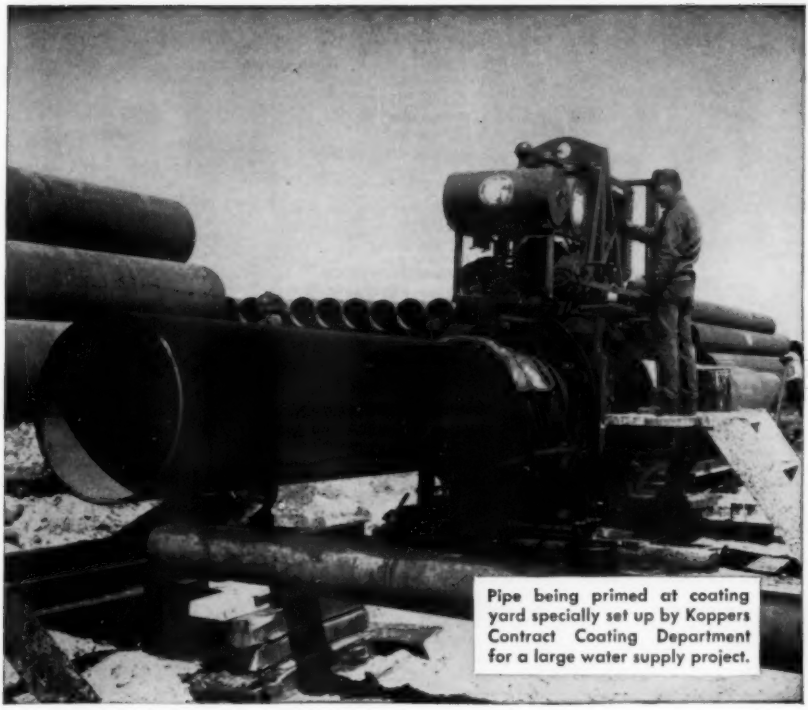

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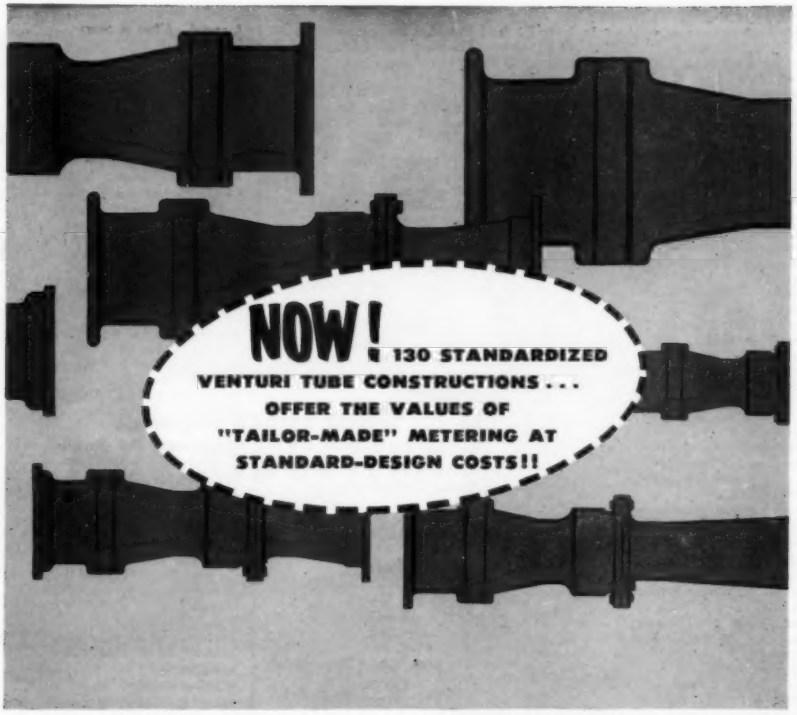

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Pittsburgh Equitable Meter Div.
Worthington-Gamon Meter Co.

Meter Reading and Record Books:
Badger Meter Mfg. Co.

Meter Testers:
Badger Meter Mfg. Co.
Ford Meter Box Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.

Meters, Domestic:
Badger Meter Mfg. Co.
Buffalo Meter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

Meters, Filtration Plant, Pumping Station, Transmission Line:
Builders-Providence, Inc. (Div., B-I-F Industries)
Burgess-Manning Co., Penn Instruments Div.
Foster Eng. Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Sparling Meter Co.

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Buffalo Meter Co.
Builders-Providence, Inc. (Div., B-I-F Industries)
Burgess-Manning Co., Penn Instruments Div.
Fischer & Porter Co.
Hersey Mfg. Co.
Neptune Meter Co.
Pittsburgh Equitable Meter Div.
Simplex Valve & Meter Co.
Sparling Meter Co.
Well Machinery & Supply Co.
Worthington-Gamon Meter Co.

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General Filter Co.
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F. B. Leopold Co.

Paints:
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Koppers Co., Inc.

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Johns-Manville Corp.
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Pipe, Brass:
American Brass Co.

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American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
Trinity Valley Iron & Steel Co.
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Cement Lined:
American Cast Iron Pipe Co.
Cast Iron Pipe Research Assn.
James B. Clow & Sons
United States Pipe & Foundry Co.
R. D. Wood Co.

Pipe, Concrete:
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American Pipe & Construction Co.
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American Brass Co.

Pipe, Steel:
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Armco Drainage & Metal Products, Inc.
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Pipe Cleaning Services:
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Pipe Coatings and Linings:
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Barrett Div.
Cast Iron Pipe Research Assn.
Centriline Corp.
Inertol Co., Inc.
Koppers Co., Inc.
Reilly Tar & Chemical Corp.

Pipe Cutters:
James B. Clow & Sons
Ellis & Ford Mfg. Co.
Jos. G. Pollard Co., Inc.
Reed Mfg. Co.
A. P. Smith Mfg. Co.
Spring Load Mfg. Corp.

Pipe Jointing Materials; see Jointing Materials

Pipe Locators:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pipe Vises:
Reed Mfg. Co.
Spring Load Mfg. Corp.

Plugs, Removable:
James B. Clow & Sons
Jos. G. Pollard Co., Inc.
A. P. Smith Mfg. Co.

Potassium Permanganate:
Carus Chemical Co.

Pressure Regulators:
Allis-Chalmers Mfg. Co.
Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Mueller Co.
Ross Valve Mfg. Co.

Pumps, Boiler Feed:
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DeLaval Steam Turbine Co.
Layne & Bowler Pump Co.
Worthington Corp.

Pumps, Centrifugal:
Allis-Chalmers Mfg. Co.
American Well Works
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.
Worthington Corp.

Pumps, Chemical Feed:
Infilco Inc.
Milton Roy Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

Pumps, Deep Well:
American Well Works
Layne & Bowler, Inc.
Layne & Bowler Pump Co.
Worthington Corp.

Pumps, Diaphragm:
Dorr-Oliver Inc.
W. S. Rockwell Co.
Wallace & Tiernan Inc.

Pumps, Hydrant:
W. S. Darley & Co.
Jos. G. Pollard Co., Inc.

Pumps, Hydraulic Booster:
Ross Valve Mfg. Co.

Pumps, Sewage:
Allis-Chalmers Mfg. Co.
DeLaval Steam Turbine Co.
C. H. Wheeler Mfg. Co.
Worthington Corp.

Pumps, Sump:
DeLaval Steam Turbine Co.
Layne & Bowler Pump Co.
C. H. Wheeler Mfg. Co.
Worthington Corp.

Pumps, Turbine:
DeLaval Steam Turbine Co.
Layne & Bowler, Inc.
Layne & Bowler Pump Co.

Recorders, Gas Density, CO_2, NH_3, SO_2, etc.:
Permutit Co.
Wallace & Tiernan Inc.

Recording Instruments:
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Burgess-Manning Co., Penn Instruments Div.
Fischer & Porter Co.
Infilco Inc.
Minneapolis-Honeywell Regulator Co.
Simplex Valve & Meter Co.
Wallace & Tiernan Inc.

Reservoirs, Steel:
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Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Tank & Mfg. Co.
Hammond Iron Works
Pittsburgh-Des Moines Steel Co.
Sparling Meter Co.

Sand Expansion Gages; see Gages

Sleeves: see Clamps

Sleeves and Valves, Tapping:
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M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
A. P. Smith Mfg. Co.

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Graver Water Conditioning Co.
Permutit Co.

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Sodium Chloride:
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International Salt Co., Inc.

Sodium Fluoride
American Agricultural Chemical Co.

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Calgon Co.

Sodium Hypochlorite:
John Wiley Jones Co.
Wallace & Tiernan Inc.

Sodium Silicate:
Philadelphia Quartz Co.

Sodium Silicofluoride
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Graver Water Conditioning Co.
Hungerford & Terry, Inc.
Infilco Inc.
Permutit Co.
Roberts Filter Mfg. Co.
Walker Process Equipment, Inc.

Softening Chemicals and Compounds:
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Cochrane Corp .
General Filter Co.
Infilco Inc.
International Salt Co., Inc.
Permutit Co.
Tennessee Corp.

Standpipes, Steel:
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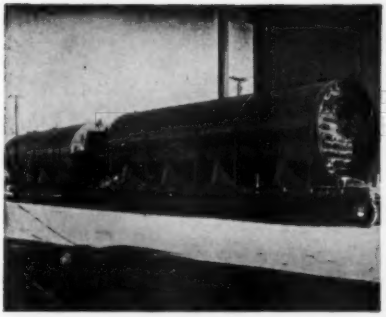
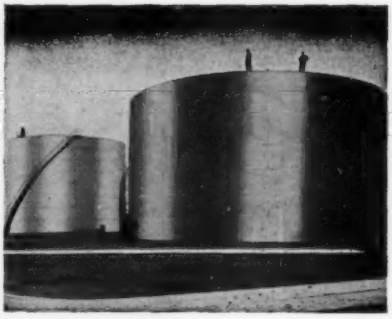
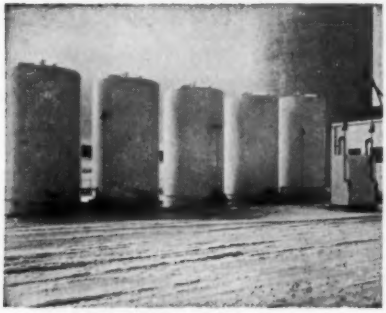
Chicago Bridge & Iron Co.
R. D. Cole Mfg. Co.
Graver Tank & Mfg. Co.





Here's the answer



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Storage Tanks: see Tanks

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Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

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Bethlehem Steel Co.
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A. P. Smith Mfg. Co.

Tapping Machines, Corp.:
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Graver Water Conditioning Co.
Industrial Chemical Sales Div.
Infilco Inc.
Permutit Co.
Proportioneers, Inc. (Div., B-I-F Industries)
Wallace & Tiernan Inc.

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DeLaval Steam Turbine Co.

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Valve Boxes:
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A. P. Smith Mfg. Co.

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Ross Valve Mfg. Co., Inc.
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DeZurik Corp.
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Darling Valve & Mfg. Co.
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Kennedy Valve Mfg. Co.
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Rensselaer Valve Co.
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Valves, Gate:
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Dresser Mfg. Div.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
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Mueller Co.
Rensselaer Valve Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
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Crane Co.
Darling Valve & Mfg. Co.
DeZurik Corp.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
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M & H Valve & Fittings Co.
Mueller Co.
Henry Pratt Co.
Rensselaer Valve Co.
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A. P. Smith Mfg. Co.
S. Morgan Smith Co.
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Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
Kennedy Valve Mfg. Co.
Ludlow Valve Mfg. Co., Inc.
M & H Valve & Fittings Co.
Muller Co.
Henry Pratt Co.
Rensselaer Valve Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
S. Morgan Smith Co.
R. D. Wood Co.

Valves, Regulating:
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Foster Eng. Co.
Golden-Anderson Valve Specialty Co.
Minneapolis-Honeywell Regulator Co.
Mueller Co.
Henry Pratt Co.
W. S. Rockwell Co.
Ross Valve Mfg. Co.
S. Morgan Smith Co.

Valves, Swing Check:
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James B. Clow & Sons
Crane Co.
Darling Valve & Mfg. Co.
Golden-Anderson Valve Specialty Co.
M. Greenberg's Sons
M & H Valve & Fittings Co.
Mueller Co.
Rensselaer Valve Co.
W. S. Rockwell Co.
A. P. Smith Mfg. Co.
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Venturi Tubes:
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Burgess-Manning Co., Penn Instruments Div.
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Simplex Valve & Meter Co.

Waterproofing:
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Water Softening Plants; see Softeners

Water Supply Contractors:
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Water Testing Apparatus:
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Chicago Bridge & Iron Co.
Cochrane Corp.
Dorr-Oliver Inc.
Etablissements Degremont
Fischer & Porter Co.
General Filter Co.
Graver Water Conditioning Co.
Hammond Iron Works
Hungerford & Terry, Inc.
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Walker Process Equipment, Inc.
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Zeolite: see Ion Exchange Materials

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When Cudahy put up its modern plant an important decision was made which assured both initial and long-term economy. It was this: Instead of graded gravel filter beds, Cudahy chose to support its sand filters with ALOXITE® aluminum oxide porous plates.

ALOXITE plates eliminated the need and cost of graded gravel and other types of underdrainage systems. And, most important, they virtually eliminated the need for filter repairs, so that the savings will increase year after year. Like all ALOXITE plate underdrains they can handle growing loads with freedom from mudballs and with minimum loss of head. And complete backwashing is accomplished without upset beds.

Construction of the new filtration plant at Cudahy was under the supervision of James Tiry, Director of Public Works and John Martinek, Water Superintendent. Answer your questions about porous media by writing for informative 56-page booklet. It's yours for the asking from:

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There's no stuffing box to leak or bind. A powerful magnetic coupling between the measuring chamber and sealed register *positively* transmits motion without mechanical linkage or seal. This friction-free construction improves meter accuracy especially on low flows.

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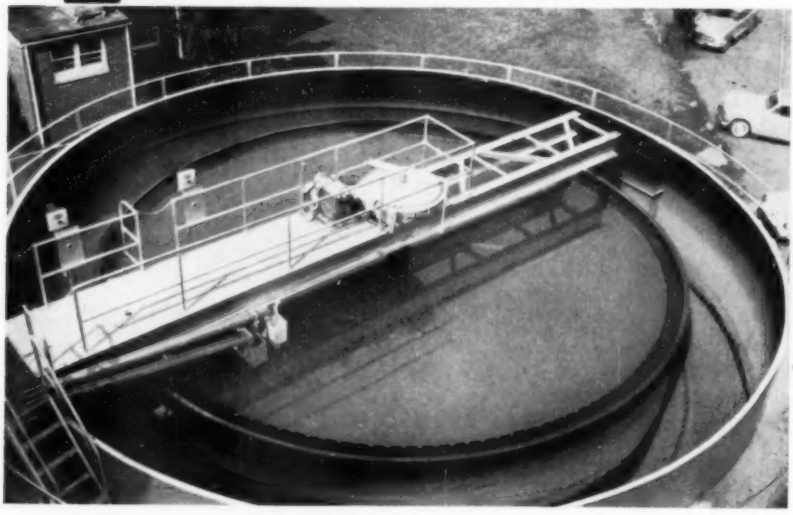
No two water treatment problems are exactly alike. The right solution to each can only be arrived at after a careful study of the local conditions. Variables such as raw water composition, rate of flow and results required automatically rule out the cure-all approach. The installation shown below is a good example of how equipment should be selected to fit the job . . . and not vice versa.



Fountain City
TENNESSEE

PeriFilter System employs split filter for continuous operation

Close up of PeriFilter System taken while backwashing right side of filter. Left side of filter remains in operation.

Consulting Engineers: Polk, Powell and Hendon, Birmingham, Alabama.

Producing 1.0 MGD of finished water from limestone springs at Fountain City, this Dorrco PeriFilter System consists of a single 30′ dia. Hydro-Treator surrounded by an annular rapid sand filter. To maintain continuous operation, the filter is split by a partition plate and backwashed one half at a time. During backwashing, Hydro-Treator effluent overflows into the inner launder and is distributed to the opposite half of the filter. The results at Fountain City have been uniformly excellent with an average turbidity in the filtered water of less than 0.3 ppm.

For more information on the complete line of D-O equipment for the water works industry write for a copy of Bulletin No. 9041. Dorr-Oliver Incorporated, Stamford, Connecticut.

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Tested and used for over 40 years.
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